PB83-259861

Swine Manure and Lagoon Effluent Applied to Fescue

North Carolina State Univ. at Raleigh

Prepared for

Robert S. Kerr Environmental Research Lab.
Ada, OK

Sep 83

U.S. Department of Commerce
National Technical Information Service
NTIS

EPA-600/2-83-078
September 1983

PB83-259861

SWINE MANURE AND LAGOON EFFLUENT APPLIED TO FESCUE

by

Philip W. Westerman
Larry D. King
Joseph C. Burns
Michael R. Overcash

School of Agriculture and Life Sciences
North Carolina State University
Raleigh, North Carolina 27650

Grant No. R-804608

Project Officer

R. Douglas Kreis
Source Management Branch
Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma 74820

ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ADA, OKLAHOMA 74820

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-83-078
2.
3. RECIPIENT'S ACCESSION NO. PB83 259861

4. TITLE AND SUBTITLE
Swine Manure and Lagoon Effluent
Applied to Fescue

5. REPORT DATE September 1983
6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
P. W. Westerman, et al.

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
School of Agriculture and Life Sciences
North Carolina State University
Box 5906
Raleigh, NC 27650

10. PROGRAM ELEMENT NO. ABPC
11. CONTRACT/GRANT NO. R-804608

12. SPONSORING AGENCY NAME AND ADDRESS
Robert S. Kerr Environmental Research Laboratory
U.S. Environmental Protection Agency
PO Box 1198
Ada, OK 74820

13. TYPE OF REPORT AND PERIOD COVERED Final ( )
14. SPONSORING AGENCY CODE EPA/600/15

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The utilization potential and the environmental effects of applying swine manure and swine lagoon effluent to tall fescue were evaluated for four years. Lagoon effluent was applied to 9 in. X 9 in. plots by weekly sprinkler irrigations during the growing season while swine manure slurry from an under-slat pit was applied to a similar plot four times per year. Treatments were chosen to evaluate the acceptable maximum application rate, which is important when land area for application is limiting. The results indicated that swine manure and swine lagoon effluent can be excellent sources of nutrients for fescue, but water quality considerations, NO_3-N levels in the forage, stand persistence and long-term soil effects must be evaluated when determing acceptable maximum application rates.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Agricultural Wastes Animal Husbandry Waste Disposal	Animal Management Land Application	43F 68D

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to Public	unclassified	154
	20. SECURITY CLASS *(This page)*	22. PRICE
	unclassified	

EPA Form 2220-1 (9-73)

NOTICE

THIS DOCUMENT HAS BEEN REPRODUCED FROM THE BEST COPY FURNISHED US BY THE SPONSORING AGENCY. ALTHOUGH IT IS RECOGNIZED THAT CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED IN THE INTEREST OF MAKING AVAILABLE AS MUCH INFORMATION AS POSSIBLE.

DISCLAIMER

Although the research described in this report has been funded wholly or in part by the United States Environmental Protection Agency through Grant No. R-804608 to North Carolina State University, Raleigh, NC, it has not been subjected to the Agency's required peer and policy review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise, and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life. In partial response to these mandates, the Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, is charged with the mission to manage research programs to investigate the nature, transport, fate, and management of pollutants in ground water and to develop and demonstrate technologies for treating wastewaters with soils and other natural systems; for controlling pollution from irrigated crop and animal production agricultural activities; for controlling pollution from petroleum refining and petrochemical industries; and for managing pollution resulting from combinations of industrial/industrial and industrial/municipal wastewaters.

This project was initiated to evaluate the utilization potential and the environmental effects of applying swine manure and swine lagoon effluent to tall fescue. Forage yield, quality and stand persistence, soil nutrient levels, and water quality and quantity of runoff were evaluated. This information is useful in determining optimal practices which will lead to the development of Best Management Practices (BMPs).

Clinton W. Hall

Clinton W. Hall, Director
Robert S. Kerr Environmental
Research Laboratory

ABSTRACT

The utilization potential and the environmental effects of applying swine manure and swine lagoon effluent to tall fescue were evaluated for four years. Lagoon effluent was applied to 9 m x 9 m plots by weekly sprinkler irrigations during the growing season while swine manure slurry from an under-slat pit was applied to a similar plot four times per year. Application rates were based on nitrogen (N) and were about 600 and 1,200 kg N/ha/yr for the lagoon-irrigated plots and about 670 kg N/ha/yr for the manured plot. These treatments resulted in much higher applications of N, phosphorus (P), potassium (K) and other nutrients than is normally used for fescue pasture. These treatments were chosen to evaluate the acceptable maximum application rate, which is important when land area for application is limiting.

Forage yield, quality and stand persistence, soil nutrient levels, and water quality and quantity of runoff were evaluated. The treatments resulted in good dry matter yields but some problems were encountered with the forage shifting away from tall fescue to tropical annuals and perennials, and with high nitrate nitrogen (NO_3-N) levels in the forage.

The results indicated that swine manure and swine lagoon effluent can be excellent sources of nutrients for fescue, but water quality considerations, NO_3-N levels in the forage, stand persistence and long-term soil effects must be evaluated when determining acceptable maximum application rates.

This report was submitted in partial fulfillment of Grant No. R-804608 by North Carolina State University under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers a period from July 5, 1976 to April 30, 1980 and work was completed as of June 30, 1982.

CONTENTS

FOREWORD iii

ABSTRACT iv

FIGURES vii

TABLES ix

ABBREVIATIONS AND SYMBOLS xii

ACKNOWLEDGMENT xiii

1. Introduction 1
2. Conclusions 3
3. Recommendations 4
4. Experimental Procedures 6
    - Site description and experimental design 6
    - Irrigation procedures 10
    - Forage experimental procedures 12
        - Statistical analysis 13
    - Soil sampling and analysis 15
    - Rainfall measurements 15
    - Rainfall runoff experimental procedures 15
    - Chemical analysis procedures 18
5. Results and Discussion 19
    - Rainfall 19
    - Irrigation applications of lagoon effluent 19
    - Manure applications 25
    - Crop response 27
    - Soil core analysis 42
    - Rainfall runoff volumes 54
    - Irrigation or irrigation-rainfall mixed runoff 55
    - Concentrations in runoff 58
    - Variation of runoff rate and concentration within an event... 70
    - Mass transport in rainfall runoff 77

REFERENCES 83

APPENDICES.. 85

A. Lagoon and irrigation data on monthly basis for 1976-1978....... 85
B. Crop response results for each year............................ 94
C. Tables of soil core results for each sampling.................. 105
D. Rainfall and runoff data....................................... 115

FIGURES

Number		Page
1	Diagram of research site for fescue plots	7
2	Annual dry matter yields	31
3	Annual amounts of N removed in forage	33
4	Annual amounts of K removed in forage	37
5	Effect of treatments on soil NO_3-N	44
6	Effect of treatments on dilute acid extractable soil P	46
7	Effect of treatments on dilute acid extractable soil K	48
8	Effect of treatments on dilute acid extractable soil Ca	49
9	Effect of treatments on dilute acid extractable soil Mg	50
10	Effect of treatments on dilute acid extractable soil Na	52
11	Effect of treatments on soil pH	53
12	Effect of treatments on mean concentrations of N, TKN and NO_3-N in rainfall runoff for entire period	63
13	Effect of treatments on mean concentration of P in rainfall runoff for entire period	64
14	Effect of treatments on mean concentrations of N, TKN, NO_3-N and NH_3-N in rainfall runoff for fourth year (3/78 - 2/79)	67
15	Effect of treatments on mean concentrations of P in rainfall runoff for fourth year (3/78 - 2/79)	68
16	Rainfall and runoff for two selected events on the manure treatment	71
17	Rain intensity, runoff rate and nutrient concentrations in runoff for event on 1-9-77 and 1-10-77	72
18	Rain intensity, runoff rate and nutrient concentrations in runoff for event on 3-13-77	73

FIGURES (continued)

Number Page

19 Variation of concentrations and associated sample volumes during the runoff event of 1-10-77 75

20 Variation of concentrations and associated sample volumes during the runoff event of 3-13-77 76

21 Mass transport of N, TKN, and NO_3-N in rainfall runoff for entire period 80

22 Annual runoff and volume-weighted concentration and mass transport of N and P 81

TABLES

Number		Page
1	Soil Particle Size Analysis, Cecil Sandy Clay Loam............	8
2	Experimental Plot Management for Fescue Plots.................	9
3	Dates of Manure and Fertilizer Applications at Fescue Site.....	11
4	Mean Seasonal Forage Height When Harvested....................	12
5	Treatment Description and Set of Meaningful Comparisons........	14
6	Periods of Various Runoff Samplers............................	16
7	Calibration Results for the Slotted Rotating Reservoir Sampler.	17
8	Monthly Rainfall at Fescue Site...............................	20
9	Irrigation Periods..	21
10	Annual Arithmetic Mean Concentrations of Lagoon Liquid and Irrigation Collection Cup Liquid...........................	22
11	Losses of TKN and NH_3-N....................................	23
12	Annual Irrigation Applications of Elements....................	24
13	Mean Annual Irrigation Applications of Elements...............	25
14	Annual Mean Concentration of Effluent.........................	25
15	Estimated Applications to Manured Plot........................	26
16	Comparing Application Amounts of Nutrients for Treatments......	27
17	Dry Matter Yields and Quantities of Elements Removed in Forage.	29
18	Treatment Comparisons of Yield, IVDMD, N and NO_3-N............	30
19	Average Concentrations of Elements in Forage..................	32
20	Treatment Comparisons of Concentrations of Minerals and Quantities Removed in the Forage...........................	34

TABLES (continued)

Number Page

21 Visual Estimates of Botanical Composition of Plots in Late Summer.. 38

22 Botanical Composition of Plots Determined in Late Fall by Hand Separation of Forage.................................. 40

23 Relative Stand Scores Designating Density of Cover Considering the Temperature Species............................ 41

24 Effect of Treatments on Soil N and Organic Matter............ 45

25 Fertility Levels for P, K, Ca and Mg for December 1978....... 54

26 Rainfall and Runoff for Designated Hydrologic Periods........ 56

27 Irrigation Runoff Volume and Concentration.................. 57

28 Rainfall-Irrigation Mixed Runoff............................ 59

29 Mass in Runoff from Irrigation and Rainfall-Irrigation Mixed. 60

30 Volume-Weighted Concentration in Rainfall Runoff............ 61

31 Mean Concentrations in Rainfall Runoff for March 1978 - February 1979.. 66

32 Highest Concentrations in Runoff for March 1978 - February 1979.. 69

33 Effect of Manure Application on Concentration in Runoff...... 74

34 Mass Transport in Rainfall Runoff............................ 78

35 Mass Transport in Rainfall Runoff for March 1978 - February 1979.. 82

Appendix

A-1 Lagoon Monthly Concentrations.............................. 86

A-2 Irrigation Collection Cup Liquid Concentrations............. 88

A-3 Ratio of Irrigation Cup Liquid Concentration to Lagoon Liquid Concentration, Monthly Means..................... 90

A-4 Monthly Irrigation Amounts.................................. 92

B-1 Yearly Dry Matter, N, and NO_3-N Yields..................... 95

TABLES (continued)

Number Page

B-2 Yearly IVDMD, N, and NO_3-N Concentrations in Forage............ 96

B-3 Yearly P, K, Ca, Mg, and Cl^- Concentrations in Forage.......... 97

B-4 Yearly Mn, Cu, Zn, Fe and Na Concentrations in Forage.......... 99

B-5 Yearly Quantities of P, K, Ca, Mg and Cl^- Removed in the Forage.. 101

B-6 Yearly Quantities of Mn, Cu, Zn, Fe and Na Removed in the Forage.. 103

C-1 Effect of Treatments on Soil NO_3-N.............................. 106

C-2 Effect of Treatments on Dilute Acid Extractable Soil P......... 107

C-3 Effect of Treatments on Dilute Acid Extractable Soil K......... 108

C-4 Effect of Treatments on Dilute Acid Extractable Soil Ca........ 109

C-5 Effect of Treatments on Dilute Acid Extractable Soil Mg........ 110

C-6 Effect of Treatments on Dilute Acid Extractable Soil Na........ 111

C-7 Effect of Treatments on Dilute Acid Extractable Soil Cu........ 112

C-8 Effect of Treatments on Dilute Acid Extractable Soil Zn........ 113

C-9 Effect of Treatments on Soil pH.................................. 114

D-1 Monthly Rainfall and Runoff...................................... 116

D-2 Rainfall and Runoff.. 119

D-3 Monthly Runoff, Mean and Highest Concentrations, and Mass Transport for March 1978 - February 1979 for TKN........... 129

D-4 Monthly Means and Highest Concentration for March 1978 - February 1979 for P.. 134

D-5 Monthly Means and Highest Concentration for March 1978 - February 1979 for NO_3-N..................................... 136

D-6 Monthly Means and Highest Concentration for March 1978 - February 1979 for N.. 138

LIST OF ABBREVIATIONS OR SYMBOLS

Ca -- calcium
CH_3COOH -- acetic acid
Cl^- -- chloride
COD -- chemical oxygen demand
Cu -- copper
Fe -- iron
HCl -- hydrochloric acid
HNO_3 -- nitric acid
H_2SO_4 -- sulfuric acid
IVDMD -- in vitro dry matter disappearance
K -- potassium
K_2O -- potash
Mg -- magnesium
Mn -- manganese
$\underline{N}$ -- normality
N -- nitrogen (total nitrogen, including nitrate nitrogen unless otherwise indicated)
Na -- sodium
NCDA -- North Carolina Department of Agriculture
NH_3-N -- ammonia nitrogen (includes ammonia nitrogen and ammonium (NH_4^+) nitrogen)
NH_4NO_3 -- ammonium nitrate
NO_2^- -- nitrite ion
NO_3^- -- nitrate ion
NO_3-N -- nitrate (NO_3^-) nitrogen
OP -- orthophosphate phosphorus
P -- total phosphorus
P_2O_5 -- phosphorus (V) oxide, often referred to as phosphate
TKN -- total Kjeldahl nitrogen (organic nitrogen plus ammonia nitrogen)
TOC -- total organic carbon
UV -- ultra violet spectrum
Zn -- zinc

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support of this project by the U.S. Environmental Protection Agency and the North Carolina Agricultural Research Service. The direction and support of EPA project officers, Lynn R. Shulyer, S. C. Yin, Don A. Clarke, and R. D. Kreis, are especially acknowledged.

The research project could not have been accomplished without the direction and support of Dr. F. J. Hassler, Head of Biological and Agricultural Engineering Department, Dr. C. B. McCants, Head of Soil Science Department and Dr. B. E. Caldwell, Head of Crop Science Department, nor without the assistance of Henry V. Marshall, Superintendent in Charge of University Research Units, J. Robert Williams, Unit II Research Unit Superintendent, and W. R. Baker, Jr., Superintendent of Central Crops Research Station. Dr. F. J. Humenik, Dr. Ronald Sneed and Dr. G. A. Cummings were largely responsible for starting the project and continued to make valuable contributions throughout the project.

A special thanks is extended to John Bentley, Ron Horton, June Preston, Dottie deBruyne, and many other field and laboratory workers who participated in this research.

Thelma Utley also deserves special thanks for her excellence in typing of the final report.

SECTION 1

INTRODUCTION

Swine production systems using confinement housing have increased in recent years. These systems normally dispose of the swine manure by (1) collecting the manure in a pit and using a tank wagon to spread the manure slurry taken from the pit, or (2) utilizing a lagoon for manure treatment and storage and pumping effluent from the lagoon to keep it from overflowing. Either disposal method has the potential for being an excellent utilization scheme for providing nutrients for growing crops.

The design of the lagoon and the requirements of the soil-plant receiver system depend largely on whether the producer's main objective is (1) manure treatment and disposal or (2) utilization of manure nutrients for useful crops. If the producer is limited by land, he may desire maximum lagoon treatment and apply lagoon effluent or manure slurry to the soil-plant receiver system at maximum rates which could be sustained without causing toxicity to plants or animals fed the plants, failure of soil structure, or excessive degradation of ground water and rainfall runoff. On the other hand, if the producer is not land-limited and he desires to utilize lagoon effluent for crop irrigation and fertilization or manure for fertilization and soil amendment, he may design the system to minimize nutrient losses and apply effluent or manure at rates based on efficient crop utilization of nutrients. Then he must decide whether to base application rate on N, P or another element. Typically, if N is the base element, P and K are applied in excess of plant utilization. However, if P is the base element, then additional N must be applied with commercial fertilizer or a manure-fertilizer blend might be utilized. Thus, depending upon the producer's objectives and the land and crop restrictions, a wide range of nutrient loading rates may be found in practice. A major question arises as to whether the maximum rate is limited by detrimental effects to crop, or soil, or by water quality of ground water and runoff.

One crop which is often utilized for application of manure and lagoon effluent is tall fescue (*Festuca arundinacea* Schreb.). It can utilize large amounts of N which is normally considered the limiting constituent in land application of manure or lagoon effluent and fescue is water tolerant and responds well to irrigation. Fescue is a cool-season perennial, however, and the continued application of nutrients and/or irrigation during the summer may cause problems with maintaining stand. The peak production of fescue in the Southeast is March through May and September through November.

The objectives of this study were to:

(1) determine dry matter yield, elemental composition, digestibility, and stand persistence of fescue receiving swine manure or swine lagoon effluent at high rates.

(2) determine soil effects of high rates of manure or lagoon effluent applications.

(3) determine effects of the various treatments on quantity and quality of rainfall runoff.

Tall fescue on a Cecil sandy clay loam was utilized in this study as the plant-soil receiver system. Treatments included commercial fertilizer, swine lagoon effluent at two rates during the growing season, and swine manure slurry applied four times a year. Application rates were based on N, and the manure and lagoon effluent supplied from 3 to 6 times more N than the commercial fertilizer treatment which used a typical fertilizer rate for fescue pasture. Also, P, K and other nutrients were supplied in the manure or effluent at several times the normal fertilization rates. Results are presented for four years of monitoring irrigation applications, crop yield and composition, soil cores, and runoff.

SECTION 2

CONCLUSIONS

Utilizing swine manure slurry and swine lagoon effluent for growing tall fescue resulted in good dry matter yields and high crude protein and digestibility, but the dry matter had excessive NO_3-N levels and vegetation shifted away from tall fescue to tropical annuals and perennials on the high-rate irrigation treatment, which indicated that the high annual rates of application and the continued application of effluent during the summer was not a good management scheme for tall fescue.

The high-rate irrigation treatment resulted in very high NO_3-N levels in the soil and the manure and low-rate irrigation treatments also had higher NO_3-N levels than the fertilized plot. The 1200 kg N/ha/yr rate was too high and the 600 kg N/ha/yr rates were probably still too high to prevent excessive nitrate movement to the groundwater and excessive NO_3-N uptake by the fescue. Maximum application rates which would be considered safe would be somewhat site specific and also depend on the amount of N lost during application and by denitrification.

No problems were encountered with nutrient imbalance of cations in the soil but continued P accumulation could eventually result in reduced iron (Fe) uptake. Periodic liming may be needed in some soils to correct for calcium (Ca) and magnesium (Mg) leaching where lagoon effluent is applied.

All treatments, including the fertilizer treatment, had some runoff events with high nutrient concentrations in runoff. Applications of manure or fertilizer without incorporation should be avoided if rain is predicted within a few days. Also, the 1200 kg N/ha/yr irrigation treatment and the manure treatment had noticably higher total N and P transport than the other treatments. Keeping application rates near normal crop fertilization rates would utilize a greater percentage of the nutrients and be more acceptable environmentally.

SECTION 3

RECOMMENDATIONS

Results of applying either swine manure slurry or swine lagoon effluent at high rates to tall fescue for four years indicated potential problems with applying three and six times the normally recommended fertilization rate based on N. Excessive NO_3-N levels resulted in the forage and in the soil when the N application was 600 or 1,200 kg/ha/yr. Also, some trends indicated potential agronomic problems if high-rate applications continued. Based upon these results the following recommendations are made:

1. Future studies should concentrate on fertilization levels in the range of 200 to 600 kg/ha/yr of N. Also, application rates of manure or lagoon effluent based on P or K should also be considered.

2. The application losses of N by NH_3-N volatilization and the soil reduction of NO_3-N by denitrification needs further study in order to better adjust application rates and determine the fate of N.

3. The potential problems of P accumulation needs further investigation.

4. The effects of high-rate applications of manure or lagoon effluent on water quality of rainfall runoff and groundwater should be studied for actual field-size systems where impact on receiving streams or impoundments could also be evaluated.

5. Other management options should be evaluated for irrigation of lagoon effluent on fescue such as using a lower application rate or no applications during the summer to help reduce stand loss of fescue to tropical annuals and perennials.

6. The potential of mixing fescue having high NO_3-N levels with other forage having low NO_3-N levels for feeding livestock needs to be evaluated.

7. Studies of this type should be conducted with various crops and soils, and different management strategies to determine which systems are best suited for utilizing manure and lagoon effluent at either normal fertilization rates or maximum disposal rates. Economics of alternatives should be evaluated. Some studies,

particularly those with high application rates, should be of five to ten years or longer duration to determine trends for long-term effects where systems are dedicated to disposal.

SECTION 4

EXPERIMENTAL PROCEDURES

The application of plant nutrients by irrigation of swine lagoon effluent and application of swine manure slurry and the fate of those nutrients through crop uptake, soil accumulation, and rainfall runoff transport were evaluated using fescue plots and standard-type procedures for collection and analysis of forage, soil cores and rainfall runoff. The study included high-rate applications of lagoon effluent during the growing season. The study period was four years.

SITE DESCRIPTION AND EXPERIMENTAL DESIGN

The experiment was conducted at the North Carolina State University Unit 2 Research Farm about 8 km south of Raleigh. The system included partially-slatted swine finishing buildings which periodically discharged pit manure slurry to a lagoon from which lagoon liquid was pumped onto the fescue plots using an automated irrigation sprinkler system. The relative outlay of the lagoons and plots are shown in Figure 1.

The vegetation on the plot area was a long-time (over 15 years) established sod of predominantly tall fescue (Festuca arundinacea Schreb.) used only periodically for grazing by beef cattle. Consequently, it had received consistent, but low fertilization in the form of swine waste from an adjacent swine confinement facility over the previous six years.

The plot site, located on a north facing slope, consisted of a Cecil sandy loam soil with eroded characteristics. The Cecil series is a member of the clayey, kaolinitic, thermic family of typic Hapludults. The A-horizon was 0 to 18 cm deep with an underlying red, firm clay 76 to 114 cm deep. The exposure had a slope of 10% and rather typical of the southeastern Piedmont region. The soil particle analysis of composited samples from the plot is given in Table 1.

The site was selected the spring of 1974. The cover was predominantly tall fescue with varying amounts of Kentucky bluegrass (Poa pratensis L.), ladino clover (Trifolium repens L.), limited orchardgrass (Dactylis glomerata L.) and some grassy and broad-leaved weeds. Tropical species were not evident.

Seven 9.2 m x 9.2 m plots (Figure 1) were staked to give four plots having a 3-5% slope and three plots 8-10% slope. The reasonably uniform and adequate cover was not disturbed. Dikes were installed along the plot

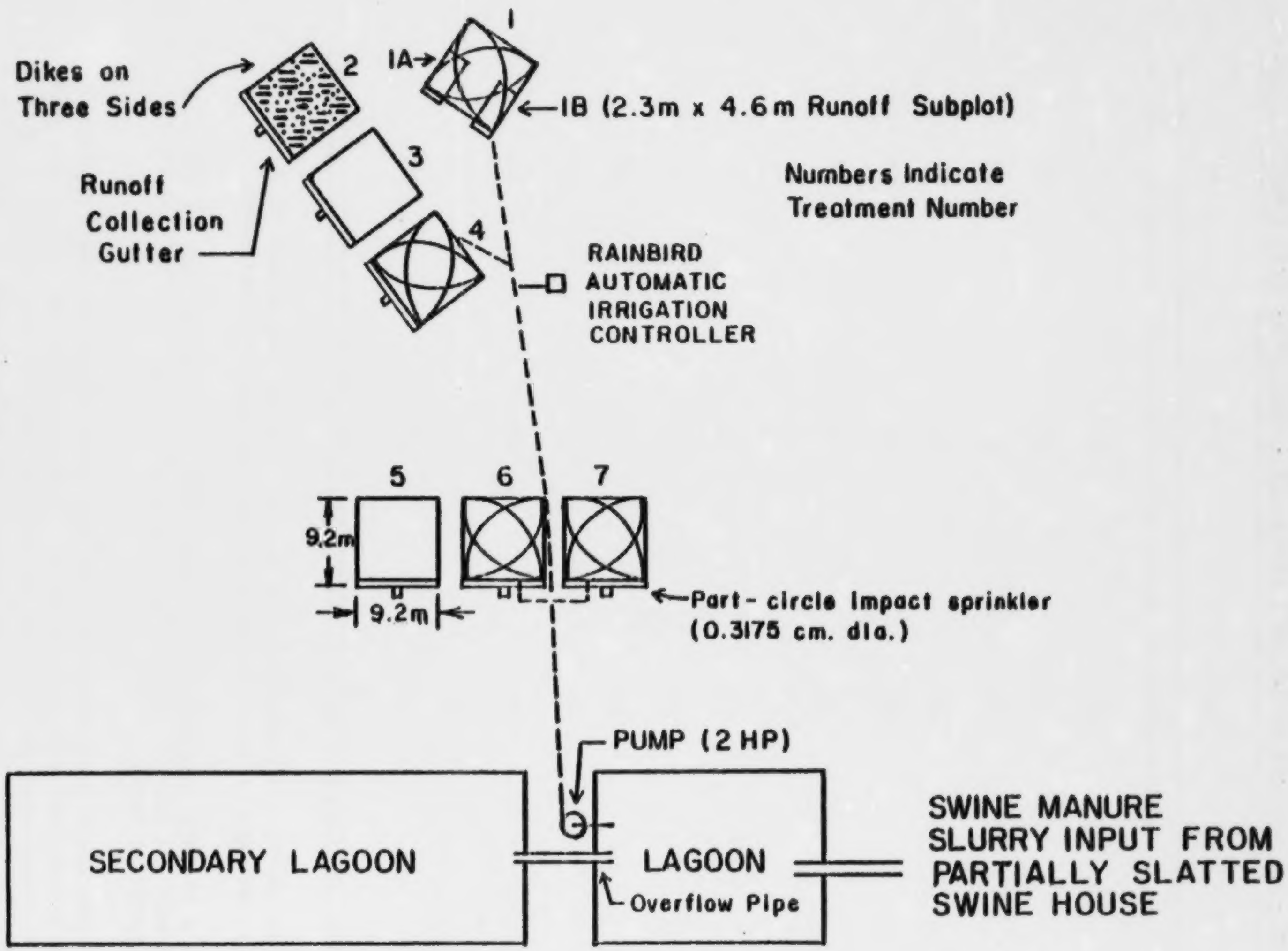
1
Dikes on
Three Sides
2
1A→
←1B (2.3m x 4.6m Runoff Subplot)
Runoff
Collection
Gutter
3
Numbers Indicate
Treatment Number
4
RAINBIRD
AUTOMATIC
IRRIGATION
CONTROLLER
5
6
7
9.2m
9.2m
←Part-circle Impact sprinkler
(0.3175 cm. dia.)
PUMP (2 HP)
SECONDARY LAGOON
LAGOON
Overflow Pipe
SWINE MANURE
SLURRY INPUT FROM
PARTIALLY SLATTED
SWINE HOUSE

Figure 1. Diagram of research site for fescue plots.

TABLE 1. SOIL PARTICLE SIZE ANALYSIS, CECIL SANDY CLAY LOAM*

Depth	Sand	Silt	Clay
cm		%	
0 - 15	59	15	25
15 - 30	41	15	45
30 - 45	29	15	56
45 - 60	25	16	60
60 - 75	26	17	57
75 - 90	32	20	48
90 - 105	35	22	42
105 - 120	43	23	33
120 - 135	51	22	27
135 - 150	49	24	27
150 - 165	53	24	23
165 - 180	55	23	22
180 - 195	59	23	18
195 - 210	53	27	20

*For a given depth, soil samples from all plots were composited to form a sample for analysis. The hydrometer method was used for analysis.

edge with a turning plow to isolate each plot. The lower edge of the plot was disturbed and fitted with gutters to collect runoff. The plots were not replicated in space.

The treatments applied to each of the seven plots are described in Table 2 with initiation in August 1974. Treatments on the 3-5% slope were a lagoon effluent loading rate and pit manure applied as a slurry to give 672 kg of N/ha, each, for the season and a recommended rate of commercial N (201/kg/ha). The three 8-10% slope plots received treatments of 672 and 1,345 kg of N/ha applied as effluent, and the control or commercial rate as noted above.

TABLE 2. EXPERIMENTAL PLOT MANAGEMENT FOR FESCUE PLOTS[†]

Tmt.[§] no.	Slope, %	Nitrogen application[*]		
		Form applied	Annual rate, kg N/ha/yr	Timing of applications
1	3-5	lagoon effluent	672	once/week from 3/1 to 11/15
2	3-5	manure from underslat pit	672	3/10, 4/15, 9/10, and 11/1
3	3-5	ammonium nitrate	201	3/10, 4/15, and 9/1
4	3-5	lagoon effluent	672	once/week from 3/1 to 11/15
5	8-10	ammonium nitrate	201	3/10, 4/15, and 9/1
6	8-10	lagoon effluent	672	once/week from 3/1 to 11/15
7	8-10	lagoon effluent	1345	once/week from 3/1 to 11/15

[†] Fescue was managed to simulate grazing by cutting the fescue at 15-20 cm back to 5 cm. Plot size was 9.2 m x 9.2 m.

[*] Application rates and timing of applications are approximate.

[§] Tmt. no. - Treatment number.

The manure slurry was obtained from the pit of a partially-slatted swine house and was applied to simulate a honey wagon application. Amounts applied were based on total Kjeldahl nitrogen (TKN) and were 168 kg/ha for each application. Applications were usually in March, April, September and November. Two applications were made in the fall of 1974. The actual dates of applications are given in Table 3.

Plots topdressed with commercial fertilizer received 34 to 65 kg/ha/yr of P and K, respectively. N was applied as ammonium nitrate (NH_4NO_3) twice in the spring and once in the fall at 67 kg/ha, totaling 201 kg of N per year. Specific application dates are shown in Table 3.

IRRIGATION PROCEDURES

For the irrigation treatments, application of the effluent from the primary lagoon was supposed to be initiated in late February each year and continue with one application per week through mid November. However, the start of irrigation was delayed several weeks in 1975 and 1976 because of problems with pumping.

The irrigation system was automated and was normally set to irrigate at night when wind effects would be minimal. To achieve uniform effluent distribution, the irrigation nozzles were located at the corner of each plot and were operated as one-quarter turn sprinklers having a radius equal to about 9.8 m. The wetted area extended outside the 9.2 m x 9.2 m area by about 0.6 m to assure total plot coverage. The various application rates were achieved by varying the irrigation time.

Irrigation equipment included a 3.8 cm diameter main header from the lagoon, a 2 HP centrifugal pump (Stayrite DHHG), laterals to each irrigated plot, electric control valves to regulate flow to sprinkler nozzles, and a time controller (Rainbird RC-12 controller). The sprinklers were operated two at a time to reduce application rate and irrigation runoff.

Samples for determining nutrient applications were taken from cups which collected irrigated lagoon effluent near the surface of the fescue plots. Samples of lagoon effluent were also taken weekly to compare to the irrigation samples. Volume of applied effluent was determined from the amount of liquid in the collection cups. In 1975, only two plots selected at random were used for irrigation analysis. Therefore, the data was combined for treatments 1, 4, and 6 and an average value was calculated. After 1975, all seven plots had collection cups.

Concentrations of N, P and other selected parameters were determined for the irrigation liquid collected on plots. Four cups were placed on the plot, with one in the center of each quadrant. Volume of collected effluent was determined for each cup and then one composite sample was taken per plot for chemical analysis. Mean concentrations were calculated for each irrigation event using the values for plots which had collection cups. Missing data occurred mainly because samples which had rainfall mixed in were not

TABLE 3. DATES OF MANURE AND FERTILIZER APPLICATIONS AT FESCUE SITE

	Manure application date[*]	P and K application date[+]	N application date[δ]
		[≠]	[≠]
1974	8 - 5		
	10 - 7		
1975	4 - 22	9 - 19	4 - 15
	5 - 6		5 - 13
	9 - 26		9 - 19
	10 - 24		
1976	3 - 3	2 - 27	2 - 27
	4 - 20		4 - 21
	9 - 8		9 - 6
	11 - 9		
1977	3 - 8	2 - 17	2 - 17
	4 - 21		4 - 19
	9 - 7		9 - 1
	11 - 8		
1978	3 - 15	3 - 15	3 - 15
	4 - 20		4 - 20
	9 - 12		9 - 1
	11 - 14		

[*] Manure application on plot 16 was swine manure from under-slat pit and rate of application based on TKN was 168 kg TKN/ha for each application. This rate required from about 0.3 cm (250 ℓ) to 1.0 cm (835 ℓ) of manure slurry on the 9.2 x 9.2 m plots depending upon TKN concentration. Amounts of P, K and other nutrients applied in the manure varied with each application.

[+] Application rates of P and K were 34 and 65 kg/ha, respectively, on plots 17 and 19.

[δ] Application rate of N was 67 kg/ha on plots 17 and 19.

[≠] Records for fertilizer applications in 1974 were lost.

included in the data. Because of missing data, monthly mean concentrations were calculated using the available weekly or irrigation event average values. The monthly mean concentrations were multiplied by the monthly amount of liquid received on each plot to determine monthly application rates of nutrients for each plot. For metals and minerals (cations), sampling for concentration analysis was usually from only one plot instead of four plots.

Lagoon liquid and irrigated effluent were analyzed for TKN, ammonia nitrogen (NH_3-N), P, Ca, Mg, sodium (Na), chloride (Cl^-), copper (Cu), zinc (Zn), chemical oxygen demand (COD), organic carbon (TOC), and during some periods orthophosphate phosphorus (OP). Methods of analyses are given in another section.

FORAGE EXPERIMENTAL PROCEDURES

Forage was harvested periodically from the plots during the spring and early summer of 1974 until treatments were initiated. The first experimental harvest occurred August 14 and thereafter during the study at a targeted height of 15-20 cm. This height was selected to keep the forage vegetative and more like under-grazing, but also to reduce harvest number. Although a grazing height of 5 to 10 cm is desired for a good grazing management, the 15-20 cm height more closely reflects actual practice. The mean height that forage was harvested at during the study (Table 4) was generally greater than that targeted, especially for the higher N rates. Because of the N and water (effluent) variables, forage for the various treatments grew at different rates. Consequently, treatments were harvested independently.

TABLE 4. MEAN SEASONAL FORAGE HEIGHT WHEN HARVESTED

Year	Land slope						
	3-5%				8-10%		
(Treatment designation)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	cm						
1974	18[§]	11	11	19	15	19	23
1975	21	14	16	21	19	21	26
1976	18	15	17	19	17	21	23
1977	21	19	16	24	20	23	28
1978	23	20	17	21	20	25	28

[§] Values are the average of the heights for each harvest within years (ranging from 4 to 9 harvests).

Two swaths were harvested the length of each plot. Harvests were generally made with a 0.53 m wide rotary mower set to cut to a 5.1 cm stubble height. The forage was bagged directly from the mower, and the green weight determined. On occasions when the forage exceeded a height easily handled by the rotary mower, a 0.46 m strip was harvested using a sickle mower. In this case the forage was raked and placed in a bag for weighing.

Forage from both swaths per plot were combined and subsampled for dry matter determination and laboratory analyses. Subsamples were dried in a forced-air oven at 75 C, ground to 1 mm through a Wiley mill and stored in plastic bags until analyzed.

Relative botanical composition estimates, as percent of vegetative cover, were obtained usually in the winter or spring and again in late summer. Botanical composition as percent of dry matter was obtained by hand separation only in the fall of 1977. Scores that reflected shifts in composition associated with tropical species were of most interest and the only ones reported.

Relative stand scores to reflect changes in stand density (weakening) were taken periodically to assess change in vegetation cover relative to bare areas which were not reflected by botanical composition data. Scores were based on a scale of 1 to 10 with 1 considered a weak, open stand and 10 a dense cover.

Stand maintenance was restricted to control of insects and periodic overseeding of plots to repair insect damage. Paraquat was used periodically only to control forage growth between plots. Plots were sprayed with 2.2 kg/ha of Sevin (80% wettable powder) in 9.4 ℓ/ha of water in September 1974 and 1977 and 4.5 kg/ha in October 1978, to control white grubs (*Cotinis nitida*). Severity of infestations were noted and all plots overseeded at 22.4 kg/ha in September 1974 and again at 8 kg/ha (16 kg/ha for treatment 7) in February and at 22.4 kg/ha in September 1977. This effort permitted continuation of the portion of the study examining surface runoff under cover associated with simulated light grazing.

Forage quality was estimated using the in vitro bioassay (Burns and Cope, 1974). Analyses were for N, P, K, Na, Ca, Mg, Cu, Zn, Fe, Cl^-, NO_3-N, and manganese (Mn).

Statistical Analyses

The forage data were analyzed using year (time) as replications. Because yield measurements in 1974 reflect only the later and less productive portion of the season, they were omitted from the analyses. This left yield, quality and mineral data from the four years, 1975 through 1978 to be analyzed.

A set of meaningful comparisons were developed (Table 5) permitting comparison between plot slope and treatments within slope. Both forage

TABLE 5. TREATMENT DESCRIPTION AND SET OF MEANINGFUL COMPARISONS

Item	Description
A) Treatments (T) 1) Lagoon effluent (672 kg N/ha)	Lagoon effluent applied weekly from March 1 through Nov. 15, 3-5% slope
2) Manure (672 kg N/ha)	Manure obtained from under slat pit in swine house, applied March 10, April 15, Sept. 10 and Nov. 1. 3-5% slope.
3) Ammonium nitrate (201 kg N/ha)	67 kg N/ha applied as a topdress March 10, April 15 and Sept. 1. 3-5% slope.
4) Lagoon effluent (672 kg N/ha).	Same as treatment 1
5) Ammonium nitrate (201 kg N/ha).	67 kg N/ha applied as a topdress March 10, April 15 and Sept. 1, 8-10% slope.
6) Lagoon effluent (672 kg N/ha)	Lagoon effluent applied weekly from March 1 through Nov. 15, 8-10% slope
7) Lagoon effluent (1345 kg N/ha)	Lagoon effluent applied weekly from March 1 through Nov. 15, 8-10% slope.
B. Meaningful comparisons	(6 degrees of freedom)
Comparison 1 (T_3 vs T_1, T_2 and T_4)	Control vs others (3-5% slope)
Comparison 2 (T_1, T_4 vs T_2	Lagoon effluent vs manure (3-5% slope)
Comparison 3 (T_1, T_3, T_4 vs T_5, T_6)	3-5% slope vs 8-10% slope
Comparison 4 (T_5 vs T_6)	Control vs effluent (8-10% slope)
Comparison 5 (T_6 vs T_7)	672 kg N/ha effluent vs 1345 kg N/ha (8-10% slope)
Comparison 6 (T_5 vs T_7)	Control vs 1345 kg N/ha from effluent (8-10% slope)

composition and yields (kg/ha) of dry matter and constituents were subjected to statistical analyses but not the botanical or stand score data.

SOIL SAMPLING AND ANALYSIS

Soil samples were taken in 15-cm increments to a depth of 120 cm during December 1975, February 1976, February 1977, and March 1978, and to a depth of 210 cm in December 1978. Four cores per plot were taken within a 2-m radius from the center of the plot. Core positions were recorded at each sampling date to prevent sampling the same position at a later date. Each time soil samples were collected from the plots, a control area receiving no swine waste and only maintenance commercial fertilizer was also sampled.

The upper 45 cm of the soil profile was sampled with a stainless steel auger. This was necessary because of the large amount of gravel in the upper part of the profile. For sampling below 45 cm, galvanized sampling tubes were driven into the soil with an electric hammer and then removed with a special jack. Holes were refilled with a sand-benotonite mixture to exclude water from the holes.

Soil cores were analyzed for extractable P, K, Ca, Mg, Na, Cu, Zn, Mn and NO_3-N and for pH. In addition, N and organic matter were determined for the December 1978 samples.

RAINFALL MEASUREMENTS

Rainfall was measured at the research site from July 1975 through February 1979 with a tipping bucket gage with event recorder. A Taylor cylinder gage was also used starting January 1976. In addition, daily rainfall was recorded at a nearby site (about 1 km) with a cylinder gage. The cylinder gage at the research site was used as the main data source after it was installed. The tipping bucket data was mainly utilized to: (1) determine specific periods of rainfall when questions arose concerning rainfall runoff or irrigation-rainfall mixed runoff, (2) compare rainfall intensity to runoff rate and concentrations in runoff for selected events, and (3) as the main data source for July 1975 through December 1975. The data from the nearby site was used for filling in missing data at the site.

RAINFALL RUNOFF EXPERIMENTAL PROCEDURES

Rainfall runoff was collected from the total plot area for all treatments except treatment 1 which had two runoff subplots 2.3 m x 4.6 m. An aluminum gutter was placed at the downslope side of the plots to collect the runoff. The interface between soil and gutter was stabilized by laying a plastic sheet that extended from the gutter back onto the plot about 10 cm. Soil was replaced to about 5 to 8 cm depth over the plastic that extended onto the plot, and then sprayed with soil/rock binder (Rock Binder, EC 5844, 3M Company).

For treatment 1, each subplot had a barrel buried in the ground to store the runoff that flowed into the gutter. However, on several events the barrels overflowed because the barrels only held about 2 cm of runoff.

For treatments 2 through 7, several runoff measurement/sampling devices were utilized over the 44-month period of runoff collection. The periods with different types of sampling are shown in Table 6.

TABLE 6. PERIODS OF VARIOUS RUNOFF SAMPLERS

Time period	Type of sampler	Possible number of samples per plot
7-11-75 to 3-25-76	Sump pump and 79-hole nozzle	34
3-26-76 to 9-23-76	Sump pump and 79-hole nozzle	1
9-24-76 to 2-28-78	Rotating reservoir with slot	34
3-1-78 to 2-28-79	Tipping bucket	1

The first sampling scheme utilized (7-11-75 to 3-25-76) was to split the flow from the gutter using a tee connection and route one-half to a sump box and allow one-half to drain down the hill. The sump box had a sump pump with float switch. When the float switch was activated due to runoff accumulation in the sump, the runoff was pumped from the sump to a 79-hole garden hose sprinkler nozzle. A small brass tube was welded over one hole to collect approximately 1/79 of the flow through the nozzle. Thus the approximate fraction of runoff collected for estimating runoff volume and for chemical analysis was 1/2 x 1/79 or 1/158 (0.633%). The runoff collected from the nozzle was routed to a box which contained a rotating distribution arm which rotated (1 revolution per four hours) in a circle over 33 wide-mouth glass jars (0.95 ℓ) and stopped over a funnel which was connected to a 208-ℓ barrel. The barrel collected the composite sample for runoff occurring after the first four hours. This sampling scheme allowed an approximation of runoff rate during the first four hours after runoff began by measuring volume of sample in each glass jar. Also, variation in concentration during the event could be evaluated by analyzing separate samples taken over time. The most prevalent problem encountered with this sampling scheme was clogging of the nozzle holes with small trash particles. Even with screens between the gutter and the sump box, the holes in the nozzle were too small to prevent clogging problems.

The sampling scheme for the periods 3-26-76 to 9-23-76 was simplified in that the runoff was pumped from the sump directly to the buried 208-ℓ barrel. This meant that one-half of total flow was collected in the barrel. This was utilized until another type of sampler could be installed.

A slotted, rotating reservoir type sampler was utilized 9-24-76 to 2-28-78. Runoff was routed from the collection gutter to a cylindrical stainless steel reservoir or bucket which was about 13 cm deep and had a diameter of 36 cm. The reservoir had one slot in the wall that started flush with the bottom of the reservoir and was 10.2 cm high. The slot was 0.64 cm wide except for the bottom 2.5 cm where the slot tapered from 0.64 cm to 0.32 cm at the bottom to allow more accuracy at low flow. Whenever runoff occurred, it flowed into the reservoir, out the slot, and drained into a metal box which had a float switch and an outflow hole. When enough runoff had occurred to activate the float switch, a 1/15 HP, 30 RPM gear-motor was automatically started which rotated the cylindrical reservoir. An L-shaped slot collector with slot width of 0.64 cm collected a portion of the flow from the rotating reservoir during each pass of the reservoir slot. The portion of flow collected in the receiver slot was routed by gravity flow to the box containing the rotating distribution arm and jars which were used with the first sampling scheme previously described. The last station (composite sample for after first 4 hr) was connected to a 7.6 ℓ container instead of a barrell because the box with jars was now below ground level in an open hole. Thus, this sampler could potentially obtain 33 samples within the first four hours after runoff began and a composite sample for the remainder of the runoff event. A metal cover prevented direct rainfall input to the rotating reservoir and the hole which housed the sampler was drained with plastic drain tube.

Each of the six slotted, rotating reservoir samplers were calibrated using a flow-meter to measure amount of water passing into the reservoir and then measuring the amount of sample collected to determine the proportion of flow which was collected. A summary of the calibration is given in Table 7.

TABLE 7. CALIBRATION RESULTS FOR THE SLOTTED ROTATING RESERVOIR SAMPLER*

Sampler number corresponding to tmt. no.	Mean flow split, %	Standard deviation, %
2	0.738	0.024
3	0.718	0.023
4	0.775	0.038
5	0.806	0.033
6	0.795	0.048
7	0.627	0.024

*Ten tests were conducted for each sampler with flow rates varying from about 2 ℓ/min to 20 ℓ/min.

The slotted, rotating reservoir sampler was moderately reliable, but there were enough problems with malfunctions (normally the electrical components and switches) that the decision was made to install a simpler sampler that would measure flow rate and take a composite sample proportional to flow. Thus, tipping bucket samplers were built and installed in February 1978.

The tipping bucket sampler was utilized 3-1-78 to 3-1-79. The bucket which tipped was a V-shaped pan of galvanized sheet metal with a divider wall in the center. The bend angle inside the "V" was 155°. The pan was on an angle-iron frame and pivoted about a support rod located beneath the pan. The stop-rest for each side of the V-shaped pan was such that water coming in at the center plane about which the pan pivoted would go into one side of the pan until it reached a certain volume and tipped, whereby the other side of the pan would then receive the water. Each half of the pan had capacity of about 2 ℓ before it would tip. A mechanical counter with arm was installed on one side to indicate the number of tips that side received, and thus allowed calculation of total tips for both sides. Also, on one side a 2.5-cm slot collector was installed in the pan upon which the tipping bucket set to collect a sample for chemical analysis. The V-shaped tipping bucket was 46 cm wide. Thus, the amount of sample collected was approximately 5.4% (2.5/46 x 100) of every other tip. The sample was routed by gravity flow to a 19 ℓ bucket for collection. This sampler was very reliable and proved to be a good sampler for small plots to obtain flow volume and a flow-proportional composite sample for chemical analysis. If flow rate is desired, an event recorder can easily be added to obtain tipping rate of the bucket.

CHEMICAL ANALYSIS PROCEDURES

Plant samples were ashed at 500 C overnight, the ash taken up in concentrated hydrochloric acid (HCl), and the resulting solution diluted to 50 mℓ (final HCl normality of 0.48 N). This solution was used for determination of P (colorimetrically), Na and K (flame photometry), and Ca, Mg, Na, Cu, Zn, and Mn (atomic absorption spectroscopy). Samples were extracted with 0.1 N nitric acid (HNO_3) plus 10% acetic acid (CH_3COOH) and analyzed for Cl^- using a chloride titrator. Samples were extracted with water and analyzed for NO_3-N using a bacteriod suspension from soybean nodules to reduce nitrate (NO_3^-) to nitrite (NO_2^-) and NO_2^- concentrations were determined colorimetrically. N was determined by the Kjeldahl procedure modified to include NO_3-N (Jackson, 1965).

Water and lagoon effluent sample analyses were basically those of Standard Methods (APHA, 1971) with modifications for automated procedures for TKN, NH_3-N, NO_3-N, Cl^-, P, and OP using the Technicon Auto Analyzer II (Technicon; 1973, 1974). The TKN analysis did not include NO_3-N. Analyses for TOC and COD were with a combination-infrared method and the dichromate reflux method, respectively. Analyses for K, Ca, Mg, Na, Cu, Zn and Mn were performed with the same methods as those used for plant samples after the water samples were evaporated to dryness.

Soil samples were air dried and extracted with water for NO_3-N (UV scan) and Cl^- (chloride titrator) and with 0.05 N HCl + 0.025 N sulfuric acid (H_2SO_4) for P (colorimetrically), K and Na (flame photometry), and Ca, Mg, Cu, Zn, and Mn (atomic absorption spectroscopy). N was determined by the Kjeldahl procedure modified to include nitrate (Jackson, 1965), organic matter by the Walkley-Black method (Jackson, 1965), and pH on a 1:1 soil: water ratio.

SECTION 5

RESULTS AND DISCUSSION

RAINFALL

Monthly and annual rainfall amounts, including the four-year monthly means are listed in Table 8, along with the normal values for Raleigh, N.C. The four-year monthly means were usually close to the normal value, except for January and March which were above normal and February, June, and August which were below normal.

Tall fescue growth occurs mainly in the spring through mid-June, and in autumn. Rainfall during the April through June period was low in 1975 and 1977, and this probably had an effect on yields in those two years. Also, long, dry periods in summer and fall can affect stands. Even though June, July and August are normally months of highest rainfall, they are also months of highest temperature and highest evapotranspiration. These months along with September and October are typified by long dry periods (4 to 8 weeks). Also, the summer months frequently have intensive rainfall periods in which appreciable runoff occurs. During this study, rainfall in June, July and August averaged below normal in all years except for July 1975 and June 1976. However, for the irrigated plots, effluent application averaged about 0.5 and 1.0 cm per week for the low-rate and high-rate plots, respectively, during the period spring through fall, and this should be considered when evaluating effects of moisture conditions. Although the weekly irrigations provided a regular moisture input, these rates possibly could have been more detrimental than beneficial in the summer months when fescue is normally in a dormant stage. Also, an increase in weeds and tropical grasses could result from effluent applications during the summer dormant season.

IRRIGATION APPLICATIONS OF LAGOON EFFLUENT

The planned irrigation period was March 1 through November 15, but irrigation began late in 1975 and 1976 (Table 9). There were some problems with sprinkler nozzles clogging with solids, particularly during the spring.

Concentrations of nutrients in the lagoon liquid varied during the irrigation season and from year to year. Monthly variation is shown in Appendix Tables A-1 and A-2. Annual arithmetic mean concentrations of lagoon liquid and irrigation collection cup liquid are shown in Table 10 for all years except 1975, when the sampling scheme was different. Elements which typically showed a 10 to 20% reduction in annual mean concentration of irrigation collection cup samples compared to the lagoon samples were TKN,

NH_3-N, P, OP, and COD. However, the concentration differences between lagoon samples and irrigation collection cup samples varied as indicated by monthly ratios given in Appendix Table A-3. Variation was likely caused by changes in sprinkler evaporation during the season, inaccuracy of sample analysis, and the fact that the lagoon samples were perhaps not always representative of the lagoon liquid which was irrigated. For conservative elements, the concentration ratio should be 1.0 or greater because of

TABLE 8. MONTHLY RAINFALL AT FESCUE SITE*

Month	Normal+	1975	1976	1977	1978	1975-1978 Mean
	Rainfall, cm					
Jan	8.5	16.8	9.7	18.6	26.0	17.8
Feb	9.6	9.9	3.4	3.8	2.9	5.0
Mar	9.5	17.8	7.1	15.7	10.3	12.7
Apr	8.6	4.2	0.8	5.8	18.6	7.4
May	10.2	6.9	13.7	7.9	9.7	9.6
Jun	10.8	6.4	12.6	1.4	9.2	7.4
Jul	14.2	31.6	3.5	3.6	11.2	12.5
Aug	13.1	2.4	6.2	10.3	5.7	6.2
Sep	9.8	24.2	9.5	15.2	3.8	13.2
Oct	7.5	4.5	14.5	13.5	5.6	9.5
Nov	6.8	9.4	5.5	7.7	11.6	8.6
Dec	8.2	12.6	11.5	7.8	8.0	10.0
Total	116.8	146.7	98.0	111.3	122.6	119.5

*Rainfall data for period July 1975 through December 1978 were taken at research site, and data from a nearby site (about 1 km away) were used for other months and any days of missing data at the site.

+Normal values are the monthly means for Raleigh, N.C. for the years 1900-1970. Source: NCSU (1971).

sprinkler evaporation and this was often the case for the metals.

TABLE 9. IRRIGATION PERIODS

Year	Irrigation period
1975	4-7 to 11-14
1976	5-6 to 11-12
1977	3-3 to 11-11
1978	3-15 to 11-10

Reductions in lagoon liquid TKN and NH_3-N concentrations with irrigation were calculated for 1977 and 1978 using only the weeks which had both a lagoon sample and irrigation collection cup liquid samples without rainfall mixed in (Table 11). Concentration reductions varied from 5 to 25% for monthly values, but averaged about 15% both years for TKN and about 18% both years for NH_3-N. Reductions were normally 20 to 25% during the summer months. These results were very similar to four years of data for a similar system at another location where Coastal bermudagrass was irrigated.

Lagoon concentrations and irrigation collection cup concentrations of nutrients varied during the season and irrigation volume was therefore varied to attempt to keep the weekly applications of nitrogen fairly uniform, but also apply the desired total amount for the season. Monthly values of irrigation volumes are given in Appendix Table A-4.

Amount of nutrients applied were calculated on a monthly basis using one monthly average concentration for all plots and the actual collection cup volumes for each plot, except in 1975 when not all plots had cups. The annual application rates are given for each irrigation plot in Table 12. The TKN loading rates desired were approached all years except 1976 when the highest and one lowest rate (treatments 7 and 1, respectively) failed to approach the 1,345 and 672 kg of N/ha. The associated minerals varied with effluent concentrations. The amounts of Cu and Zn irrigated were low because they settle in the lagoon sludge (Overcash et al., 1978). The mean annual application amounts for the four years are shown in Table 13.

The effective mean concentrations of elements in the irrigated lagoon liquid are shown in Table 14. The concentration of N and all minerals analyzed were generally higher in both 1976 and 1977 than either 1975 or 1978.

For grazed tall fescue, normal fertilizer recommendations for North Carolina are about 220 kg N/ha in split applications, usually in February and early September, and a ratio of 4-1-2 for N-P_2O_5 - K_2O (about 9-1-4 for N-P-K) (Dobson et al., 1977). The N-P-K ratio applied with lagoon effluent averaged about 5-1-11. Thus, in ratio to N, the amounts of P and K applied

TABLE 10. ANNUAL ARITHMETIC MEAN CONCENTRATIONS OF LAGOON LIQUID AND IRRIGATION COLLECTION CUP LIQUID[*]

Year	N	P	K	Ca	Mg	Na	Cl^-
Lagoon liquid mean concentrations, mg/ℓ							
1976	530	77	1,060	115	36	490	450
1977	470	91	630	65	19	310	420
1978	330	81	370	74	28	210	310
Irrigation collection cup liquid mean concentrations, mg/ℓ							
1976	410	54	-	108	35	-	518
1977	390	79	740	80	28	373	437
1978[†]	280	68	380	61	23	241	304
Concentration ratio of collection cup liquid to lagoon sample[§]							
1976	0.77	0.70	-	0.94	0.97	-	1.15
1977	0.83	0.87	1.17	1.23	1.47	1.20	1.04
1978[†]	0.85	0.84	1.02	0.82	0.82	1.15	0.98

Year	Cu	Zn	COD	TOC	OP	NH_3-N
Lagoon liquid mean concentrations, mg/ℓ						
1976	0.17	0.72	2,200	900	53	420
1977	0.08	0.55	1,800	450	82	390
1978	0.12	0.93	1,600	500	66	260
Irrigation collection cup liquid mean concentrations, mg/ℓ						
1976	0.28	1.3	1,900	900	-	-
1977	0.28	0.80	1,600	450	73	320
1978[†]	0.09	0.50	1,400	400	52	220
Concentration ratio of collection cup liquid to lagoon sample[§]						
1976	1.65	1.80	0.86	1.00	-	-
1977	3.50	1.45	0.89	1.00	0.89	0.82
1978[†]	0.75	0.54	0.88	0.80	0.79	0.85

---

[*] Normally, weekly values were averaged to obtain a monthly mean; then the monthly means were averaged to obtain the annual mean concentration.

[†] During 1978, irrigation cups had funnel inserts to reduce evaporation and ammonia volatilization. Based on data from a similar situation, the effect of funnels would be less than 10%.

[§] There is no adjustment for evaporation from the irrigation sprinkler application or from the collection cups.

TABLE 11. LOSSES OF TKN AND NH_3-N

		Lagoon concentration, mg/ℓ		NH_3-N	Reduction in concentration in collection cups, %†	
Month	n*	TKN	NH_3-N	TKN	TKN	NH_3-N
1977						
March	4	590	470	.80	15	11
April	3	440	400	.91	2	5
May	2	520	490	.94	15	12
June	4	440	400	.91	20	20
July	4	520	470	.90	14	26
Aug.	2	550	370	.67	18	22
Sept.	4	440	300	.68	16	17
Oct.	2	420	330	.78	17	24
Mean		490	400	.82	15	17
1978						
March	3	470	380	.81	13	5
April	4	470	450	.96	9	13
May	3	380	350	.92	11	14
June	3	310	280	.90	16	21
July	2	310	240	.77	26	25
Aug.	4	270	180	.67	15	17
Sept.	4	280	160	.57	14	25
Oct.	3	250	170	.68	8	24
Mean		340	280	.78	14	18

* Only used data from weeks which had both lagoon and collection cup samples without rainfall mixed in. Number of weeks with both samples is n.

† Losses based on concentration; evaporation losses not included. Irrigation was normally at night. Collection cups had funnel inserts in 1978 to reduce evaporation and volatilization. In 1977, one or two plots normally had cups with and without funnels and very little effect was found.

were about 2 times and 4 times more than the normally-recommended ratio. Also, because N was applied about 3 times and 6 times the normally-recommended pasture rate, the amounts of P and K were about 6 times and 24 times the normal fertilizer rate. Applications of several other elements were also much greater than normal.

TABLE 12. ANNUAL IRRIGATION APPLICATIONS OF ELEMENTS

Year	Tmt. no.	Effluent applied, cm	Amount of element applied, kg/ha*								
			N	P	K	Ca	Mg	Na	Cl$^-$	Cu	Zn
1975+	1	20.1	549	107	987	140	86	418	-	0.31	0.77
	4	20.1	549	107	987	140	86	418	-	0.31	0.77
	6	20.1	549	107	987	140	86	418	-	0.31	0.77
	7	50.0	1,351	265	2,523	337	208	1,022	-	0.66	1.75
1976δ	1	10.2	439	56	1,082	116	41	490	461	0.26	1.21
	4	13.2	563	72	1,410	148	54	636	594	0.34	1.61
	6	12.9	546	71	1,365	143	48	631	595	0.34	1.56
	7	22.6	942	121	2,447	251	94	1,080	993	0.59	2.91
1977	1	13.7	549	111	957	112	32	503	620	0.40	1.15
	4	15.8	628	127	1,109	130	37	579	718	0.42	1.31
	6	17.2	695	140	1,233	146	41	628	785	0.49	1.49
	7	31.9	1,266	254	2,273	260	74	1,155	1,470	0.83	2.64
1978	1	24.8	699	172	921	149	58	592	753	0.20	1.25
	4	25.4	715	178	930	153	60	614	771	0.21	1.26
	6	23.2	622	163	826	140	57	566	698	0.18	1.12
	7	46.5	1,287	326	1,719	277	110	1,121	1,411	0.38	2.29

[*] Calculated by multiplying monthly mean concentration in collection cups by monthly amount of liquid received on each plot (as measured by 4 collection cups per plot). Monthly mean concentrations were calculated using one mean concentration for each irrigation event that had data and no rainfall mixed in, using normally 1 composite sample per plot from all four plots for N and P analyses but from only 1 plot for metals and minerals analyses.

[+] 1975 - Only 2 plots selected at random were used for irrigation check for each event. Therefore, the data was combined for plots 14, 18, and 20 and an average value calculated.

[δ] Lagoon sample concentrations instead of cup sample concentrations were used to calculate K and Na amounts.

TABLE 13. MEAN ANNUAL IRRIGATION APPLICATIONS OF ELEMENTS

Tmt. no.	Effluent applied, cm	Mean annual amount of element applied, kg/ha								
		N	P	K	Ca	Mg	Na	Cl^-	Cu	Zn
1	17.2	559	112	987	129	55	501	611	0.29	1.10
4	18.6	614	121	1,109	143	59	562	694	0.32	1.24
6	18.4	603	120	1,103	142	58	561	693	0.33	1.24
7	37.8	1,212	242	2,241	281	122	1,095	1,291	0.62	2.40

TABLE 14. ANNUAL MEAN CONCENTRATION OF EFFLUENT[*]

Year	Irrigated effluent concentration, mg/ℓ								
	N	P	K	Ca	Mg	Na	Cl^-	Cu	Zn
1975	272	53	494	69	43	207	-	0.14	0.37
1976[δ]	424	54	1,068[δ]	112	40	482[δ]	450	0.26	1.23
1977	400	80	707	83	23	365	456	0.28	0.84
1978	277	70	366	60	24	242	303	0.08	0.50

[*] Effective mean calculated by dividing total mass applied by total volume applied.

[δ] 1976 K and Na values are from lagoon samples.

MANURE APPLICATIONS

Swine manure slurry from a collection pit in a partially-slatted finishing house was applied four times each year to treatment 2. Application rate was based on the TKN of the manure slurry and varied from about 0.3 cm (250 ℓ) to 1.0 cm (835 ℓ) on the 9.2 m x 9.2 m plots in order to apply 168 kg TKN/ha each application. The ratio of other nutrients or elements to TKN also varied with each application and data was not obtained for several nutrients for all applications. Therefore, data for this same facility taken biweekly over about a 15-month period (Humenik and Overcash, 1976; Overcash and Humenik, 1976) was used to estimate amounts of other elements applied (Table 15).

TABLE 15. ESTIMATED APPLICATIONS TO MANURED PLOT

Parameter	Ratio[§] to N	Amount applied per application, kg/ha	Amount applied per year, kg/ha
TKN[*]	1.0	168	672
COD[*]	14.4	2,420	9,680
TOC[*]	3.70	620	2,480
P[*]	0.29	49	196
OP[*]	0.21	35	140
NH_4-N[*]	0.52	87	348
Cl^-[*]	0.28	47	188
K[+]	0.41	69	276
Ca[+]	0.44	74	296
Mg[+]	0.10	17	67
Na[+]	0.15	25	101
Mn[+]	0.0038	0.6	2.4
Cu[+]	0.00064	0.11	0.44
Zn[+]	0.0064	1.1	4.3

[§] Ratios were on a percent of total solids basis.

[*] Ratios are for samples taken at the same swine facility for underslat pit effluent emptied once/two weeks and mixed in mixing tank. From Humenik and Overcash (1976, p. 45).

[+] Ratios of these elements to P were taken from Overcash and Humenik (1976, p. 55) for the same swine facility for underslat pit effluent. These were used in conjunction with the P:TKN ratio of 0.29 from above data to calculate ratios to TKN.

The N-P-K ratio of the applied manure was about 3.4-1-1.4. Compared to the normally-recommended fertilizer ratio of about 9-1-4, the manure was high in P (about 2.5 times) and all right for K in relation to N, whereas lagoon effluent was high in both P and K in relation to N. However, the NH_3-N level is high for both lagoon liquid (about 80% of TKN) and swine manure from the pit (about 50% of TKN), and if NH_3-N loss occurs during and after applications, these ratios will change. For surface applications, ammonia loss could be significant. Ammonia loss would thus increase the excess of P and K in relation to N.

Comparing the lagoon-irrigated treatment with the manure treatment receiving the same amount of N approximately, the irrigated treatment received much more (about 4 times) K, Na and Cl^- while the manure treatment received more P, Ca, and Zn on an annual basis (Table 16). Other differences between the treatments were the amount of water received (about 10 to 25 cm more for the low-rate irrigated treatments) and the frequency of application (about 30 weekly irrigations compared to four manure applications per year).

TABLE 16. COMPARING APPLICATION AMOUNTS OF NUTRIENTS FOR TREATMENTS

	Annual application, kg/ha								
Treatment	N	P	K	Ca	Mg	Na	Cl^-	Cu	Zn
Fertilizer	201	34	65	-	-	-	-	-	-
Manure	672	196	276	296	67	101	188	0.44	4.3
Low effluent[§]	592	118	1,066	138	57	541	666	0.31	1.2
High effluent[≠]	1,212	242	2,241	281	122	1,095	1,291	0.62	2.4

[§] Mean of 3 treatments (tmts. 1, 4 and 6) for 4-year period.

[≠] Mean for 4 years.

CROP RESPONSE

This portion of the overall study examined the influence of several lagoon effluent loading rates and simulated honey wagon spreading of manure pit contents on the dry matter yield, constituents' concentrations, potential quality of the forage and stand persistence compared to plots with conventional commercial fertilizer applications. The objectives were: 1) to determine dry matter yield and stand persistence of temperate species receiving applications of effluent throughout the summer; 2) to determine N, NO_3-N, and mineral concentrations that could accumulate in the forage and the quantities that were removed per unit area; and 3) to obtain estimates of the quality of the harvested forage through in vitro dry matter disappearance (IVDMD).

Dry Matter Yield

Mean dry matter yields (Table 17) from the control (treatment 3) plot on the 3-5% slope produced less forage than the effluent or manure treatments for the same slope (comparison 1, Table 5,B and Table 18,B; 6,938 kg/ha vs 9,817). Also N applied as effluent produced greater yields compared with manure (comparison 2, Table 5,B and Table 18,B). Yields obtained from the 3-5% slope were similar to those on the 8-10% slope (comparison 3, Table 5,B and Table 18,B). Among treatments of the 8-10% slope, effluent application increased yields over the control (comparison 4, Table 5,B and 18,B), but applying 1,345 kg of N/ha did not increase yields over the 672 rate (comparison 5, Table 5,B and 18,B). Clearly N applications as effluent was advantageous in stimulating dry matter production. However, little response occurred above the 672 kg of N/ha loading rate.

Examination of the year-to-year variation in dry matter production (Figure 2 and Appendix Table B-6) shows yields to increase from 1975 through 1976 for all treatments, then decline in 1977 and increase again in 1978. Such shifts are associated with rainfall patterns during the spring growth periods; however, the relative changes are greater for treatment 7 and will be discussed more under the section presenting botanical composition and stand score data.

Nutritive Evaluation

The IVDMD concentrations in the harvested forage (Table 19) were quite satisfactory to provide energy intake for good yearling daily gains. Further, N concentrations far exceeded normal requirements of growing livestock. NO_3-N concentrations when converted to NO_3^- as percent of dry matter were quite high relative to levels normally considered safe for ruminants. NO_3^- concentrations for treatments receiving either effluent (treatments 1, 4, 6, 7) or manure (treatment 2) ranged from 0.65 to 1.2% with 0.3% of the dry matter as NO_3^- considered as being potentially toxic [Hojjati et. al. (1972); Murphy and Smith (1967)]. Levels of NO_3^- in treatments 3 and 5 would generally be safe.

Examining the treatment comparisons for concentrations in the forage (Table 5,A and 18,A) show that IVDMD was not altered by the type of nutrient source applied, rate of application or plot slope. N was increased only in forage treated with the highest effluent rate (1345 kg N/ha). NO_3-N concentrations were significantly altered by either effluent loading rate or manure application. Further, the highest effluent rate increased NO_3-N concentrations 74% over the lower effluent rate.

The quantity of estimated digestible nutrients produced per hectare ranged from 4,643 to 8,339 kg (Table 17). However, of particular interest is the quantities of N and NO_3-N that could be removed in the forage dry matter. N removal ranged from 240 to 432 kg/ha and NO_3-N from 5 to 33 kg/ha.

Examining the various treatment comparisons showed the large influence of dry matter yields on constituent removal because IVDMD and N patterns were identical to dry matter yields. NO_3-N removal (kg/ha) had a somewhat

TABLE 17. DRY MATTER YIELDS AND QUANTITIES OF ELEMENTS REMOVED IN FORAGE

	Land slope						
	3-5%				8-10%		
Item	Lagoon effluent (672 kg N/ha	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent 1345 kg N/ha)
(Tmt. no.)[‡]	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	kg/ha						
Dry matter	10,880[†]	7,583	6,938	10,987	8,792	11,674	12,495
Estimated digestible dry matter	7,229	5,224	4,643	7,626	5,908	7,859	8,339
N	366	278	240	389	285	391	432
NO_3-N	16	14	5	18	7	17	33
P	41	30	23	43	31	47	52
K	391	255	204	410	239	446	516
Ca	37	31	29	36	35	37	45
Mg	34	25	24	35	30	36	41
Mn	0.4	0.6	0.2	0.5	1.0	0.6	0.8
Na	12	5	3	13	5	15	20
Cl^-	160	88	80	170	85	168	165
Fe	9	7	4	5	6	6	8
Cu	0.09	0.08	0.06	0.08	0.07	0.08	0.09
Zn	0.4	0.6	0.3	0.4	0.4	0.5	0.6

[‡] Tmt. no. - Treatment number.

[†] Each value is the mean of four years (replications) summed for all harvests within each year.

TABLE 18. TREATMENT COMPARISONS OF YIELD, IVDMD, N AND NO_3-N

		Quality constituents		
Comparison	Dry matter yield	IVDMD (%)	N (%)	NO_3-N (ppm)
A. Concentrations in the forage:				
C1	—	66.8 vs 68.0	3.4 vs 3.5	575 vs 1,644**
C2	--	67.7 vs 68.5	3.4 vs 3.7	1,549 vs 1,833
C3	—	67.4 vs 67.3	3.4 vs 3.3	1,224 vs 1,158
C4	--	67.5 vs 67.0	3.2 vs 3.4	758 vs 1,558
C5	--	67.0 vs 67.0	3.4 vs 3.5	1,558 vs 2,714*
C6	--	67.5 vs 67.0	3.2 vs 3.5*	758 vs 2,714**
B. Quantities produced or removed in the dry matter (kg/ha)				
C1	6,938 vs 9,817**	4,643 vs 6,693**	240 vs 344**	5 vs 16**
C2	10,934 vs 7,583**	7,428 vs 5,224**	378 vs 278**	17 vs 14
C3	9,602 vs 10,233	6,499 vs 6,884	332 vs 338	13 vs 12
C4	8,792 vs 11,674**	5,908 vs 7,859**	285 vs 391**	7 vs 17*
C5	11,674 vs 12,495	7,859 vs 8,339	391 vs 432	17 vs 33**
C6	8,792 vs 12,495**	5,908 vs 8,339**	285 vs 432**	7 vs 33**

*, ** = $P \leq 0.05$ and $P \leq 0.01$, respectively.

different pattern as no difference was noted between effluent and manure treatment (comparison 2, Table 5,B and 18,B), but higher removal resulted from the 1,345 kg of N/ha treatment vs 672. Year-to-year changes for these constituents are reported in Appendix Tables C-1 and C-2, and for N in Figure 3.

Mineral Concentrations and Quantities Removed in the Forage

Treatment concentrations for the minerals analyzed are shown in Table 19. Comparisons of interest (Table 20) within the 3-5% slope treatment showed P, K, Cl^-, Na, Cu and Zn concentrations to be increased by either effluent or manure loading. Ca concentrations were reduced while Mg, Mn and Fe were not altered. Forage receiving lagoon effluent compared with manure had higher concentrations of only Cl^- and Na, and lower concentrations of Ca, Mn, Cu and Zn. Levels of P, K, Mg and Fe were not altered.

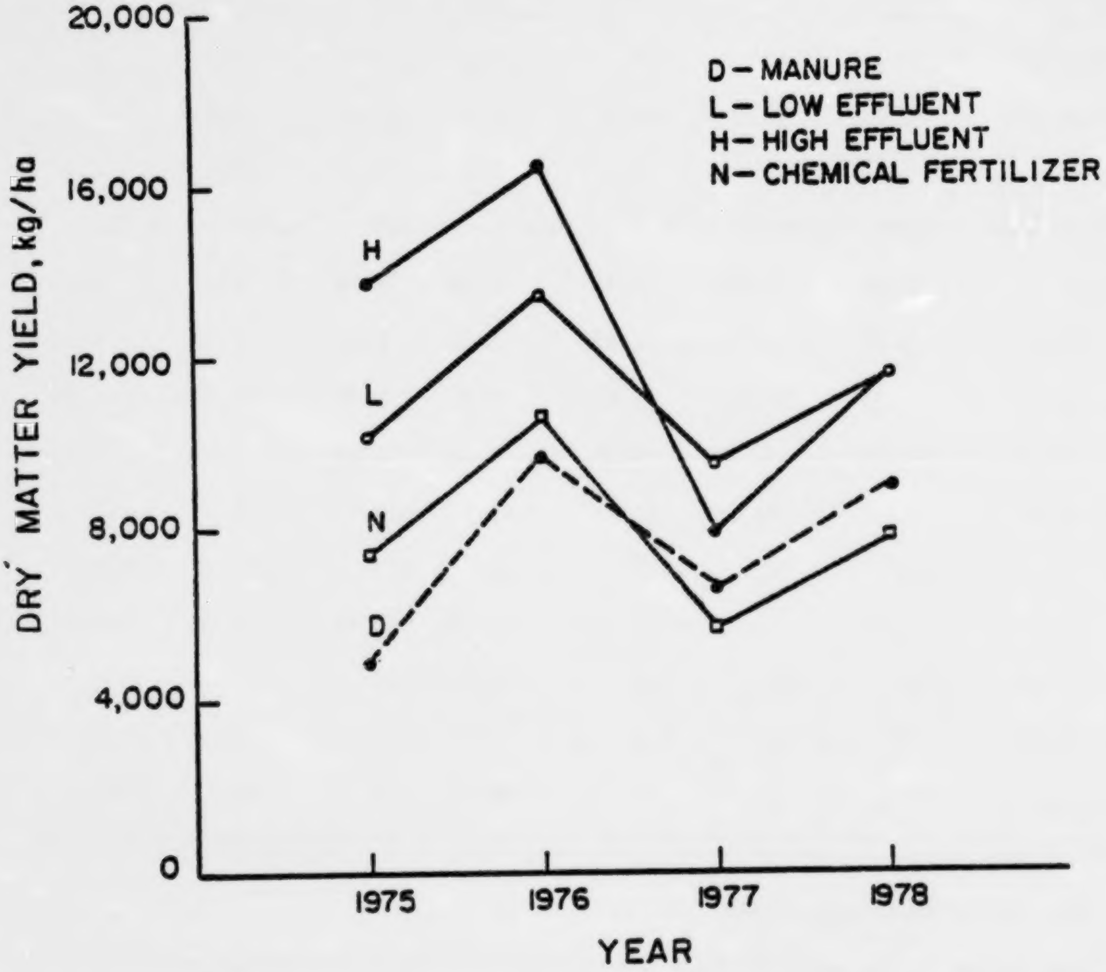

Figure 2. Annual dry matter yields.

TABLE 19. AVERAGE CONCENTRATIONS OF ELEMENTS IN FORAGE

	Land slope						
	3-5%				8-10%		
Item	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)
(Tmt. no)[‡]	(1)	(2)	(3)	(4)	(5)	(6)	(7)
IVDMD (%)	66.2[†]	68.5	66.8	69.2	67.5	67.0	67.0
N(%)	3.4	3.7	3.4	3.5	3.2	3.4	3.5
NO_3-N (ppm)	1,474	1,833	575	1,624	758	1,558	2,714
P (%)	0.38	0.40	0.32	0.39	0.36	0.41	0.42
K (%)	3.61	3.33	2.88	3.72	2.72	3.82	4.18
Ca (%)	0.34	0.43	0.43	0.34	0.39	0.32	0.36
Mg (%)	0.31	0.33	0.35	0.32	0.35	0.31	0.33
Mn (ppm)	38	76	35	45	115	57	63
Na (ppm)	1,168	700	428	1,163	630	1,269	1,686
Cl^- (%)	1.47	1.14	1.14	1.55	0.97	1.44	1.36
Fe (ppm)	795	904	682	476	631	501	583
Cu (ppm)	9	11	8	8	8	7	7
Zn (ppm)	39	69	41	40	46	43	51

[‡] Tmt. no. - Treatment number

[†] Each value is the mean of four years (replications) weighted within each year for dry matter produced at each harvest.

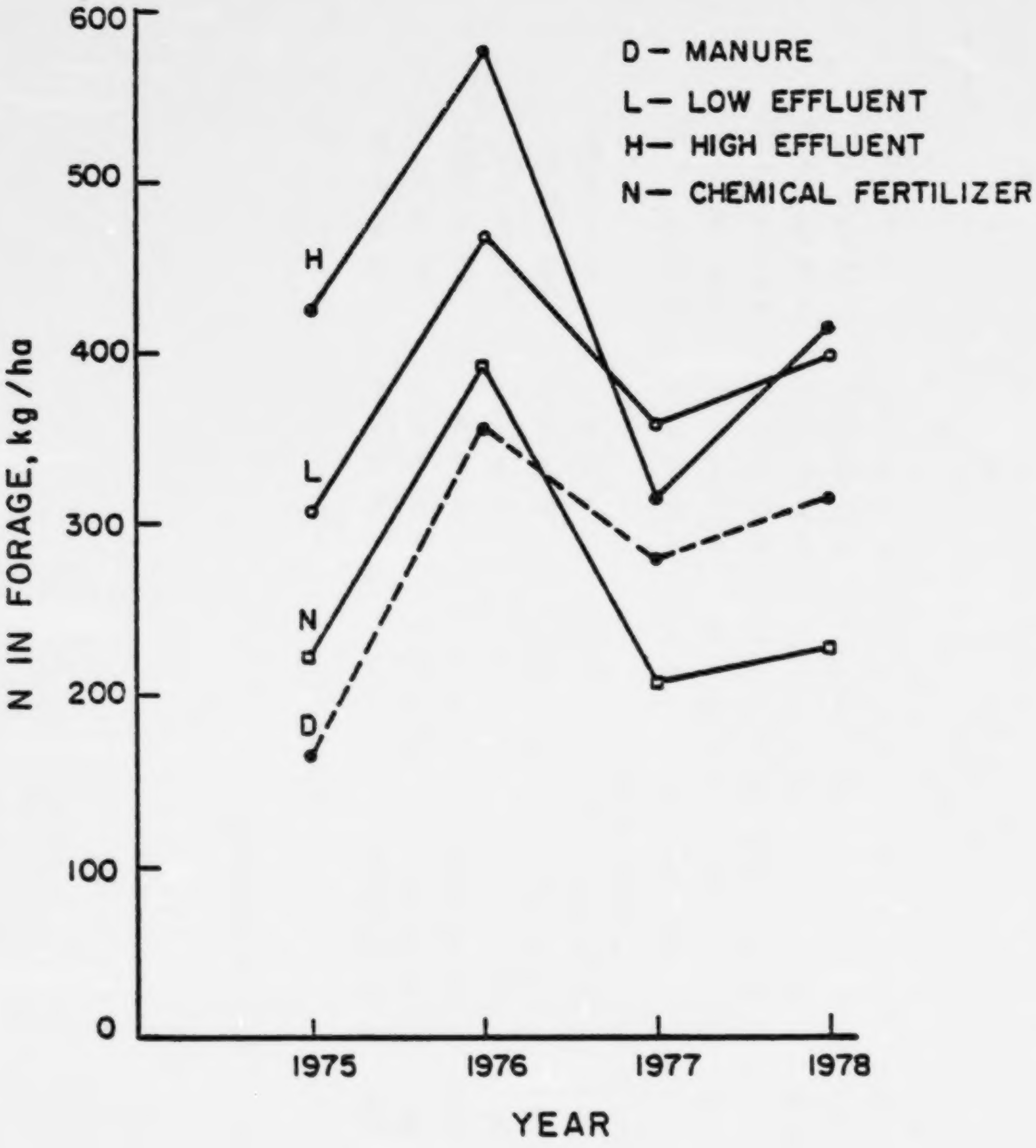

Figure 3. Annual amounts of N removed in forage.

TABLE 20. TREATMENT COMPARISONS OF CONCENTRATIONS OF MINERALS AND QUANTITIES REMOVED IN THE FORAGE

	Minerals				
Comparison	P	K	Ca	Mg	Cl^-
A. Concentrations in forage (%)					
C 1	0.32 vs 0.39**	2.88 vs 3.55**	0.43 vs 0.37**	0.35 vs 0.32	1.14 vs 1.39**
C 2	0.39 vs 0.40	3.67 vs 3.33	0.34 vs 0.43**	0.32 vs 0.33	1.51 vs 1.14**
C 3	0.36 vs 0.39	3.40 vs 3.27	0.37 vs 0.36	0.33 vs 0.33	1.39 vs 1.21**
C 4	0.36 vs 0.41*	2.72 vs 3.82**	0.39 vs 0.32**	0.35 vs 0.31*	0.97 vs 1.44**
C 5	0.41 vs 0.42	3.82 vs 4.18	0.32 vs 0.36	0.31 vs 0.33	1.44 vs 1.36
C 6	0.36 vs 0.42**	2.72 vs 4.18**	0.39 vs 0.36	0.35 vs 0.33	0.97 vs 1.36**
B. Quantities removed in the dry matter (kg/ha)					
C 1	23 vs 38**	204 vs 352**	29 vs 35	24 vs 31*	80 vs 139**
C 2	42 vs 30**	401 vs 255**	37 vs 31	35 vs 25**	165 vs 88**
C 3	36 vs 39	355 vs 343	34 vs 36	31 vs 33	137 vs 127
C 4	31 vs 47**	239 vs 446**	35 vs 37	30 vs 36	85 vs 168**
C 5	47 vs 52	446 vs 516	37 vs 45*	36 vs 41	168 vs 165
C 6	31 vs 52**	239 vs 516**	35 vs 45*	30 vs 41**	85 vs 165**

(continued)

*,** = $P \leq 0.05$ and $P \leq 0.01$, respectively.

TABLE 20 (continued)

	Minerals				
Comparison	Mn	Na	Fe	Cu	Zn
A. Concentration in forage (ppm)					
C 1	35 vs 53	428 vs 1,010**	682 vs 725	8 vs 9*	41 vs 49*
C 2	42 vs 76**	1,166 vs 704**	636 vs 904	9 vs 11**	40 vs 69**
C 3	39 vs 86**	920 vs 950	651 vs 566	8 vs 8	40 vs 45
C 4	115 vs 57**	630 vs 1,269**	631 vs 501	8 vs 7	46 vs 43
C 5	57 vs 63	1,269 vs 1,686**	501 vs 583	7 vs 7	43 vs 51
C 6	115 vs 63**	630 vs 1,686**	631 vs 583	8 vs 7	46 vs 51
B. Quantities removed in the dry matter (kg/ha)					
C 1	0.2 vs 0.5*	3 vs 10**	4 vs 7	.06 vs .08**	0.3 vs 0.5**
C 2	0.5 vs 0.6	13 vs 5**	7 vs 7	.09 vs .08	0.4 vs 0.6
C 3	0.4 vs 0.8**	9 vs 10	6 vs 6	.08 vs .08	0.4 vs 0.5
C 4	1.0 vs 0.6**	5 vs 15**	6 vs 6	.07 vs .08	0.4 vs 0.5
C 5	0.6 vs 0.8	15 vs 20**	6 vs 8	.08 vs .09	0.5 vs 0.6
C 6	1.0 vs 0.8	5 vs 20**	6 vs 8	.07 vs .09*	0.4 vs 0.6**

*,** = $P \leq 0.05$ and $P \leq 0.01$, respectively.

The slope of plot influenced only Cl^- and Mn with forage from the lower slope having high Cl^- and lower Mn levels. The pattern for mineral concentrations in forage from the control in the 8-10% slope plots compared with forage receiving effluent were similar to that of the 3-5% slope, except for higher Mg and Mn and no difference in Cu. Only the Na concentrations were increased in forage from the high effluent rate compared with the lower. The pattern for the control vs the high effluent loading rate (comparison 6, Table 5,B) was similar to comparison 1 (Table 20,A).

Treatment comparisons for the quantities of the various minerals removed in the dry matter show P, K, Mg, Cl^- and Na to have similar patterns as dry matter yield (Tables 18,B and 20,B). Ca removed in the forage was greater only for the high effluent loading rate. The effluent treatments did not significantly increase Mg removed in forage harvested on the 8-10% slope. Only Mn was influenced by slope with higher quantities removed in forage from the steeper slope, but quantities removed were not influenced by the high effluent rate.

Removal of Na was greater from the higher loading rate over the lower while Fe removal was not altered by any treatment. Both Cu and Zn had lower removal (kg/ha) in the control than when forage received either effluent or manure. Year-to-year differences in concentrations and quantities removed in the forage are shown in Appendix Tables B-3, B-4, B-5 and B-6, and for K in Figure 4.

Stand Persistence and Shifts in Botanical Composition

Tall fescue growth occurs mainly in the spring through mid-June with a midsummer dormant period associated with high temperature and variable periods of water stress (drought). Regrowth resumes in the autumn with the onset of cooler days and September rains. Continuous application of nitrogen as occurred for treatments 1, 4, 6 and 7 during the summer might adversely effect persistence of tall fescue or other temperature grasses.

At the beginning of this study (late summer 1974) the cover on all plots was similar in general composition (Table 21). The temperate grasses accounted for 78 to 90% of the vegetation. Ladino clover accounted for 8 to 15% of the vegetation and some grassy and broadleaf weeds were evident ranging from 0 to 10%.

A year later (1975) clover had been nearly eliminated in all plots with only an estimated 5% remaining in treatments 1 and 4. Some decline (21% units) of the temperate grasses had occurred in treatment 7. By late summer, 1977 the temperate grasses in treatment 7 made up only 45% of the vegetation. Some reduction in the temperate grasses' contribution to the total vegetation was also evident in treatments 5 and 6.

The reduction in the temperate grasses was associated with increases in two tropical grasses, i.e., bermudagrass (*Cynodon dactylon* Pers. L.) and crabgrass (*Digitaria* spp.) ranging in a combined total from 25 to 35% of the vegetation. Also the broadleaf weeds percentage in treatment 7 doubled. A

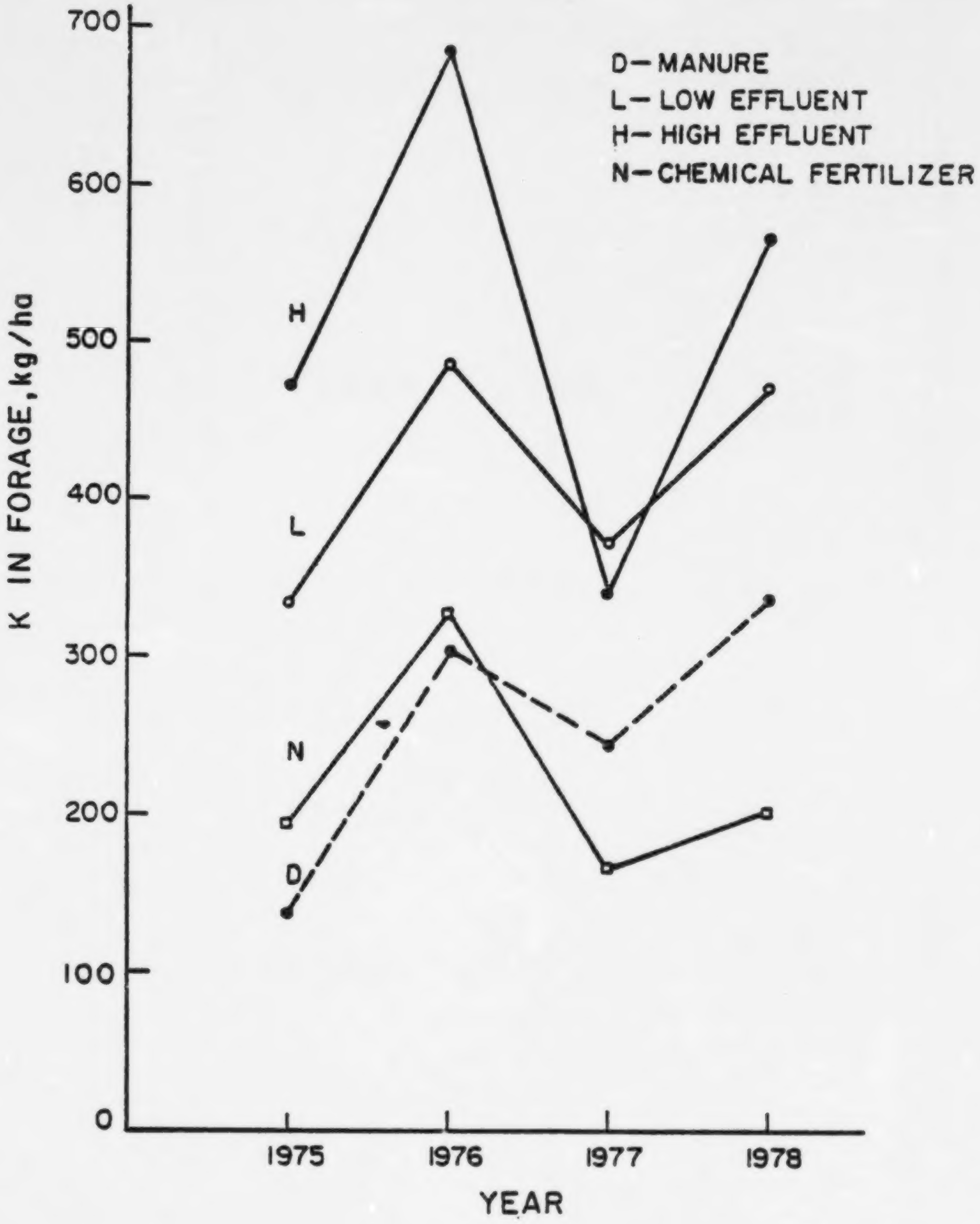

Figure 4. Annual amounts of K removed in forage.

TABLE 21. VISUAL ESTIMATES OF BOTANICAL COMPOSITION OF PLOTS IN LATE SUMMER

	Land slope						
	3-5%				8-10%		
Item	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)
(Treatment number)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	%						
1974:							
Ladino clover	9	12	10	15	10	8	8
Temperate grasses	90	87	88	83	85	85	78
Weedy grasses	0	0	2	1	1	6	4
Weeds (bd. leaf)[+]	1	1	0	1	4	1	10
1975:							
Ladino clover	5	1	0	5	0	0	3
Temperate grasses	85	90	91	88	92	80	57
Tall fescue	85	60	51	58	80	55	52
Bluegrass	0	30	40	30	12	25	5
Tropical grasses	0	6	6	3	3	8	30
Weeds (bd. leaf)	10	3	3	4	5	12	10

(continued)

TABLE 21 (continued)

Item	Land slope						
	3-5%				8-10%		
	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)
(Treatment number)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	%						
1977:							
Ladino clover	0	0	0	0	0	0	0
Temperate grasses	85	82	92	86	71	65	45
Tall fescue	55	78	32	76	51	50	45
Bluegrass	30	4	60	10	20	15	0
Tropical grasses	15	15	0	10	25	30	35
Bermudagrass	0	10	5	0	10	15	20
Crabgrass	15	5	0	10	15	15	15
Weeds (bd. leaf)	0	3	3	4	4	5	20
1978:							
Ladino clover	2	0	2	2	0	5	5
Temperate grasses	40	40	80	30	20	0	0
Tall fescue	40	40	80	30	20	0	0
Bluegrass	0	0	0	0	0	0	0
Tropical grasses	58	35	13	28	62	50	95
Bermudagrass	0	10	3	0	0	5	45
Crabgrass	58	25	10	28	62	45	50
Weedy grasses	0	23	0	40	15	45	0
Weeds (bd. leaf)	0	2	5	0	3	0	0

[+] Bd. leaf = broadleaf

hand separation was made in October 1977 to better document these shifts (Table 22). The October date was selected to obtain an estimate of both the temperate and tropical grass contributions to the total vegetation cover.

TABLE 22. BOTANICAL COMPOSITION OF PLOTS DETERMINED IN LATE FALL BY HAND SEPARATION OF FORAGE

	Land slope						
	3-5%				8-10%		
Item	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)
(Tmt. no.)[†]	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	%						
Ladino clover	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperate grasses	100.0	96.7	81.8	100.0	99.0	84.3	38.6
Tall fescue	85.4	67.0	27.2	89.1	62.6	74.7	38.6
Blue-grass	14.6	15.4	54.6	10.9	36.4	9.6	t
Orchard-grass	0.0	14.3	0.0	0.0	0.0	0.0	0.0
Tropical grasses	0.0	0.0	18.2	0.0	0.0	15.7	53.2
Bermuda-grass	0.0	0.0	18.2	0.0	0.0	15.7	26.6
Crabgrass	0.0	0.0	0.0	0.0	0.0	0.0	26.6
Weeds (bd. leaf)[+]	0.0	3.3	0.0	0.0	1.0	t	8.2

[†] Tmt. no. - Treatment number.

[+] Bd. leaf = broadleaf; t = trace

Temperate grasses, as percent of the total dry matter, had not been appreciably reduced in treatments 1, 2, 3, 4, 5 and 6 (Table 22). However, the temperate grasses comprised only 38.6% of the total vegetation in treatment 7 with essentially no bluegrass remaining and appreciable reductions in the tall fescue contribution. Both bermudagrass and crabgrass had increased in treatment 7 totaling 53.2% of the total dry matter. Bermudagrass was also present in treatment 3 totaling 18.2% of the vegetation.

Estimates by late summer, 1978, showed the presence of crabgrass in all treatments (Table 21) and bermudagrass in treatments 2, 3, 6 and 7. On this date, tropical grasses were estimated to account for nearly all the cover (95%) on treatments 7 and 13 to 62% of the vegetation on the other six treatments. Also weedy grasses increased up to 40 and 45% of the vegetation on treatments 4 and 6, respectively.

The changes noted above in the botanical composition cannot be attributed totally to the treatment imposed because initially an old tall fescue sod had been selected for the study. It is unlikely that such contaminants as bermudagrass and crabgrass were uniformly spread over the experimental site. Consequently, their presence in one plot and not the other might be expected. However, appreciable increases in these contaminants does indicate a general weakening of the temperate grass stand and the inability of the temperate species to persist and retain the tropical species only in contaminants.

Stand density scores were recorded periodically during the study as an index to original stand survival. Although botanical composition provides insight into changes in the vegetation present, it does not indicate the vigor or density of that vegetation. Stand scores (1 designated a weak open stand and 10 a dense cover) clearly show treatments 1, 4, 6 and 7, those receiving effluent, to have appreciably deteriorated by 1978 (Table 23). These treatments had large bare areas with the tropical species taking over treatments 6 and 7. The shift was occurring in spite of the overseeding of tall fescue in both 1974 and 1977. The shift in botanical composition may be partially reflected in the large decrease in dry matter yield from 1976 to 1977 (Appendix Table B-1). This reduction was especially large for treatment 7. Forage stands on the other four treatments (2, 3, 4 and 5) were either changed little or the density increased.

TABLE 23. RELATIVE STAND SCORES DESIGNATING DENSITY OF COVER CONSIDERING THE TEMPERATE SPECIES

	Land slope						
	3-5%				8-10%		
Item	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)
(Tmt. no.)[†]	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1975	9[*]	4	6	10	8	9	8
1977	8	4	7	8	8	9	3
1978	2	5	10	4	9	2	1

[†] Tmt. no. - Treatment number

[*] Stand scores are 1 = weak, open stand and 10 = dense cover.

It should be noted that white grub infestations occurred in all sod in the fall of 1974, 1977 and 1978. However, grub populations were always consistently high in treatment 7. This high population appeared related to this specific treatment. These data indicate that an effluent waste system that requires weekly applications during the summer should not use temperate grasses as a cover. Stands will likely thin and deteriorate with eventual invasion of crabgrass, bermudagrass and weeds on sites similar to the one in this study.

Summary of Crop Response

Examining the results from this section of the study allows the following conclusions. The treatments used resulted in respectable dry matter yields which would remove sizable quantities of N and other minerals from the immediate environment. The estimabed digestibility (IVDMD) of the dry matter produced was generally similar among treatments and quite good. Further the crude protein (N% x 6.25) concentrations for all treatments was quite high (ranged from 20 to 23%) and would exceed most animal requirements. The major mineral (P, K, Ca and Mg) concentrations, although somewhat higher in the lagoon effluent and manure treatment than normally found in forage tissue, should create no problem. Of the other minerals, only Na seems unusually high, but should not be a major factor in animal health.

The only fraction that appears to be in excess and a possible health hazard is the NO_3-N levels of treatments receiving either lagoon effluent or manure. Only those topdressed with NH_4NO_3 appear totally safe. Because of the high quality (high IVDMD and N concentrations) of the dry matter produced, a possible use of this forage would be a blend with another feed generally low in N. This would dilute the excessively high NO_3^- in the forage from the effluent or manure treatments and increase the overall N and possibly the digestibility of the material it was blended with.

The potential of using cool season plants in a southern environment as a reservoir for continually dumping nutrients during the summer is quite limited. Although dry matter yields stayed high, there was a striking shift away from tall fescue to tropical annuals and perennials in plots receiving effluent or manure. Effluent caused greater shifts than did manure. In some cases tall fescue completely disappeared. Further, the higher rates of N cause major insect infestations causing appreciable bare ground.

In conclusion, it appears that while the yield and quality of the forage produced is quite satisfactory, some dilution would be required before feeding to animals. Further, at the rates of effluent or manure evaluated, tall fescue should not be the plant used because stands would be very short lived. The scheme of application is more conducive to tropical grasses, perhaps grown in sequence with annual grasses.

SOIL CORE ANALYSIS

Applications of nutrients at several times the normal fertilization rates resulted in accumulation of nutrients in the soil. For the highest application rate (treatment 7), about 1,345 kg/ha of N was applied each year but only 432 kg N/ha was recovered in forage on the average. Thus, about 900 kg N/ha, minus losses at application, was not removed in the forage each year and could possibly accumulate in the soil, be transported by surface runoff or leached to groundwater, or be denitrified. Chemical reactions, microbial transformations, soil absorption and relative mobility for soil-water movement are widely different for various elements. Thus, some elements such as P tend to accumulate and some elements such as N tend to be leached from the root zone.

The objectives of analyzing soil cores were: (1) to determine accumulation of nutrients in the soil for the various treatments, and (2) detect any physical or chemical changes in the soil that may adversely affect long-term productivity. Since all treatments were not replicated, it was not possible to statistically analyze the data. Consequently, only large differences among treatments will be considered real and other differences will not be discussed.

Soil NO_3-N

In December 1975, the high effluent irrigation rate resulted in increased NO_3-N concentrations in the profile (Figure 5). Much of this NO_3-N was not leached by winter rains and was still present in the profile in February 1976. The high rate continued to cause high soil NO_3-N concentrations throughout the experimental period. By 1977, manure applications began to result in increased NO_3-N levels. The low irrigation rate usually resulted in somewhat higher soil NO_3-N compared to the control and fertilizer treatments. The control and chemical fertilizer treatments were essentially identical throughout the experiment.

Soil N and Organic Matter

N concentrations were similar among treatments in the 0-30 cm soil layer (Table 24). At lower depths the high effluent rate appeared to cause higher N concentrations and this was probably due to the NO_3-N component of the N.

None of the treatments increased the organic matter content of the 0-30 cm soil layer. The data suggest that some treatments slightly increased organic matter at lower depths. However, since most waste treatments were not very different from the chemical fertilizer treatment, it appears that the effect of treatments was to stimulate plant growth and thus provide a greater root mass which, upon sloughing, was incorporated into the soil organic matter.

Soil P

There was little effect on soil P concentrations in February 1976 (Figure 6). As time progressed, P concentrations in plots receiving the two effluent irrigation rates increased. There was a less dramatic increase in soil P due to manure and inorganic fertilizer. By December 1978, soil P concentrations

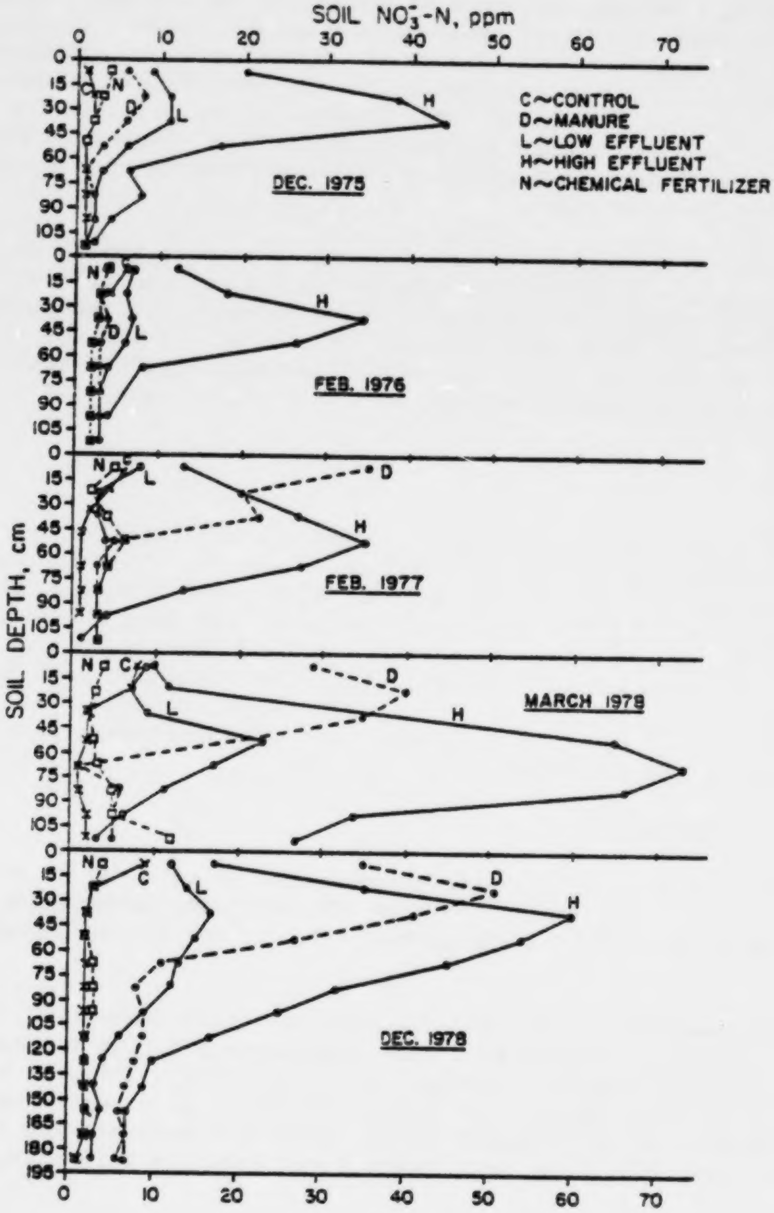

Figure 5. Effect of treatments on soil NO_3-N.

TABLE 24. EFFECT OF TREATMENTS ON SOIL N AND ORGANIC MATTER

	N					Organic Matter				
	Treatments					Treatments				
Depth	Low[†]	High[§]	Manure	NPK[*]	Control	Low	High	Manure	NPK	Control
cm	µg/g					%				
0-30	770	752	684	698	704	1.54	1.61	1.27	1.58	1.68
30-60	311	410	307	268	223	.52	.66	.42	.53	.39
60-90	178	203	116	147	89	.23	.24	.17	.21	.12
90-120	102	118	108	90	47	.13	.10	.12	.10	.05
120-180	60	60	88	52	32	.07	.09	.08	.06	.04
180-210	46	74	80	38	38	.03	.06	.08	.03	.03
210-240	42	54	76	33	44	.04	.03	.02	.03	.05

[†] Low-low-rate effluent treatments (treatments 1, 4, and 6).

[§] High-high-rate effluent treatments (treatment 7).

[*] NPK - Fertilized treatments (treatments 3 and 5).

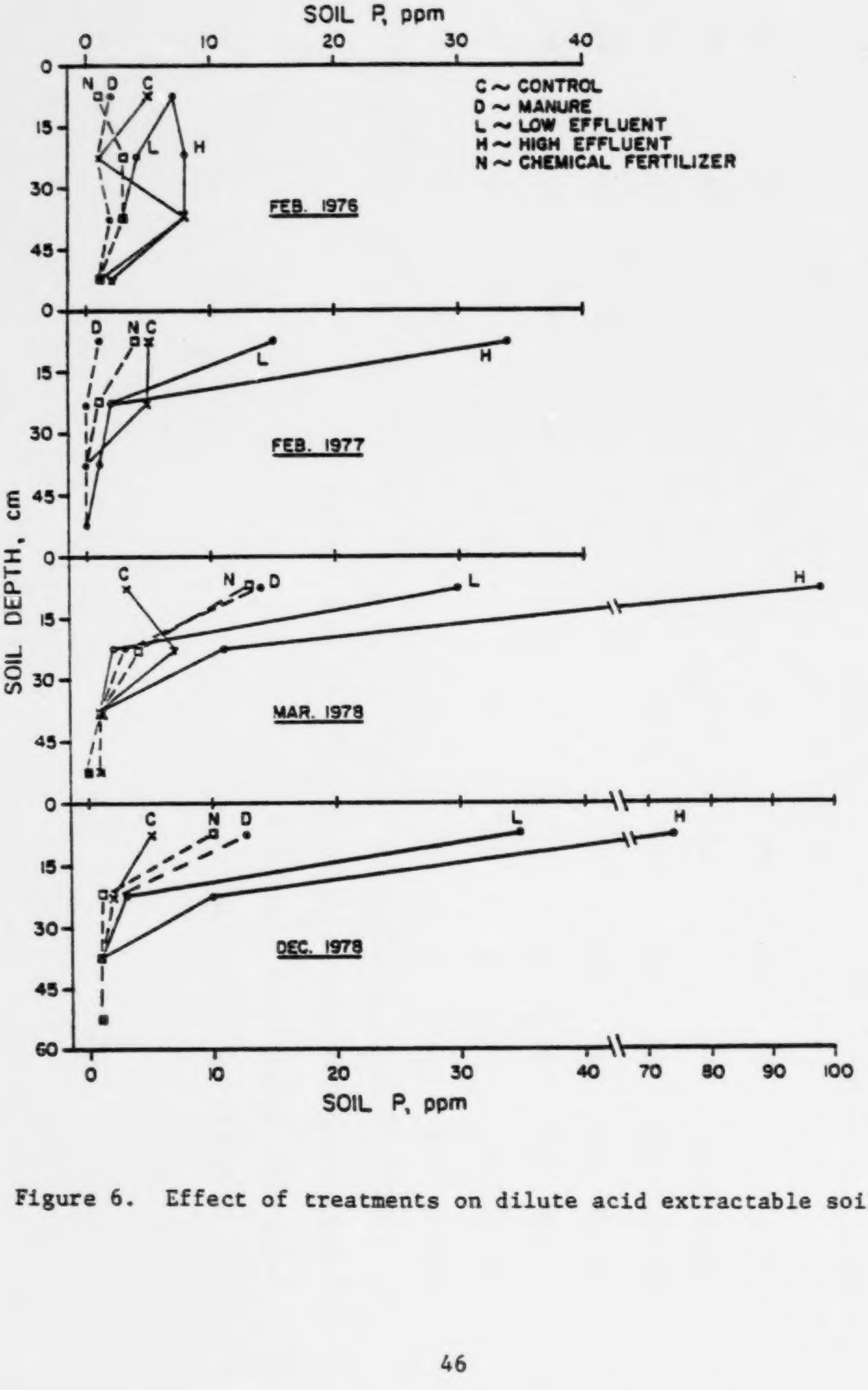

Figure 6. Effect of treatments on dilute acid extractable soil P.

in the 0-15 cm layer were in the following fertility levels according to the North Carolina Department of Agriculture (NCDA) fertility classification system:

Treatment	Fertility level
Control and chemical fertilizer	low
Manure	medium
Low effluent rate	high
High effluent rate	very high

In the 15-30 cm layer it appears that the high effluent rate caused an increase in soil P, thus indicating some downward movement.

Soil K

The two effluent irrigation rates caused large increases in soil K concentrations at all sampling dates (Figure 7). Manure additions resulted in higher soil K than did chemical fertilizer but concentrations with manure were not much different from concentrations in the control plots. K concentrations were lower with chemical fertilizer than with the control treatment. This was to be expected because the fertilizer treatment supplied 65 kg K/ha/yr while average crop removal was 190 kg K/ha/yr. The control plot was not harvested so K simply was recycled on this plot.

There was some downward movement of K, but there was little movement below 100 cm. Fertility levels in the 0-15 cm layer in December 1978 were:

Treatment	Fertility level
Chemical fertilizer	medium
Control	high
All waste treatments	very high

Soil Ca

There was little consistent effect of treatments on soil Ca concentrations (Figure 8). Fertility levels in the 0-15 cm layer in December 1978 were: manure - "very high"; all other treatments - "high".

Soil Mg

Generally, soil Mg was higher in the fertilizer and manure treatments than in the effluent treatments (Figure 9). This resulted from more leaching of Mg in the effluent treatments. In December 1978, it was noted that some of the Mg leached out of the upper profile at the high effluent

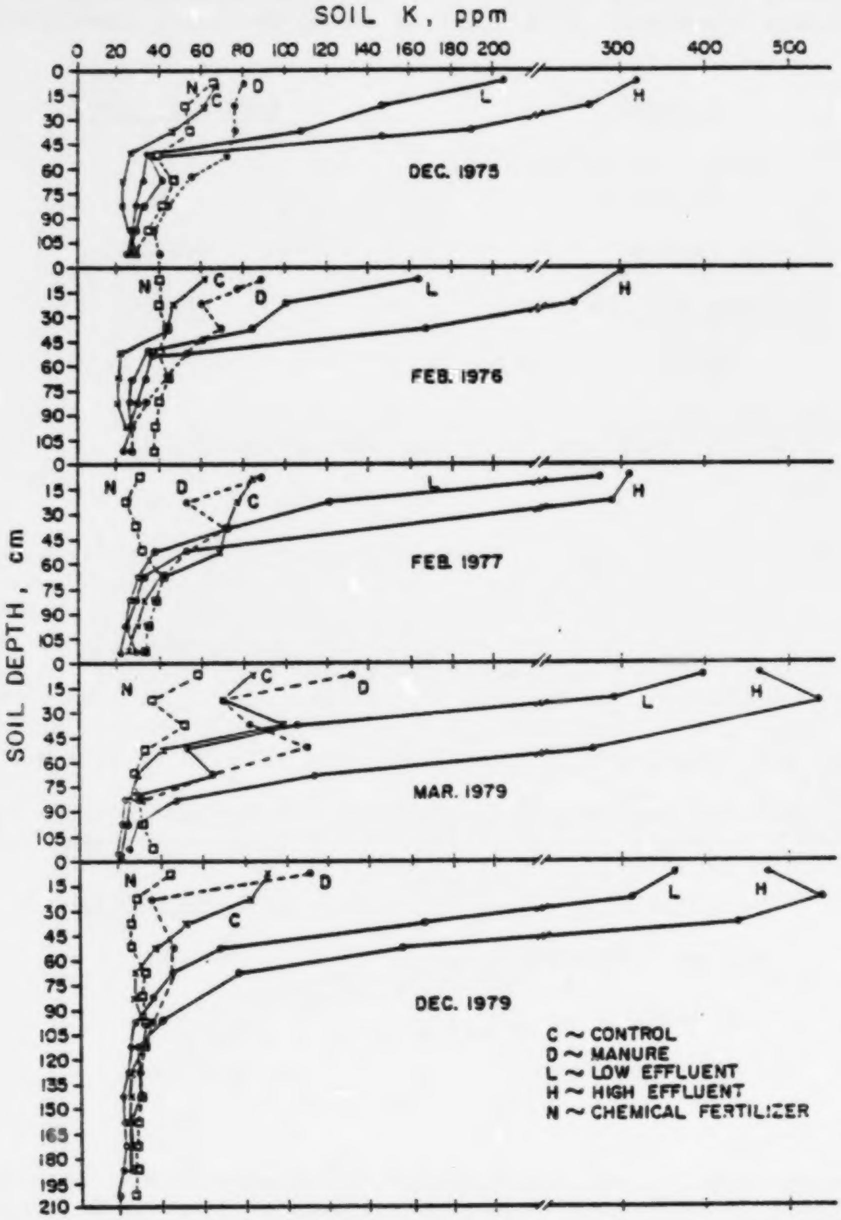

Figure 7. Effect of treatments on dilute acid extractable soil K.

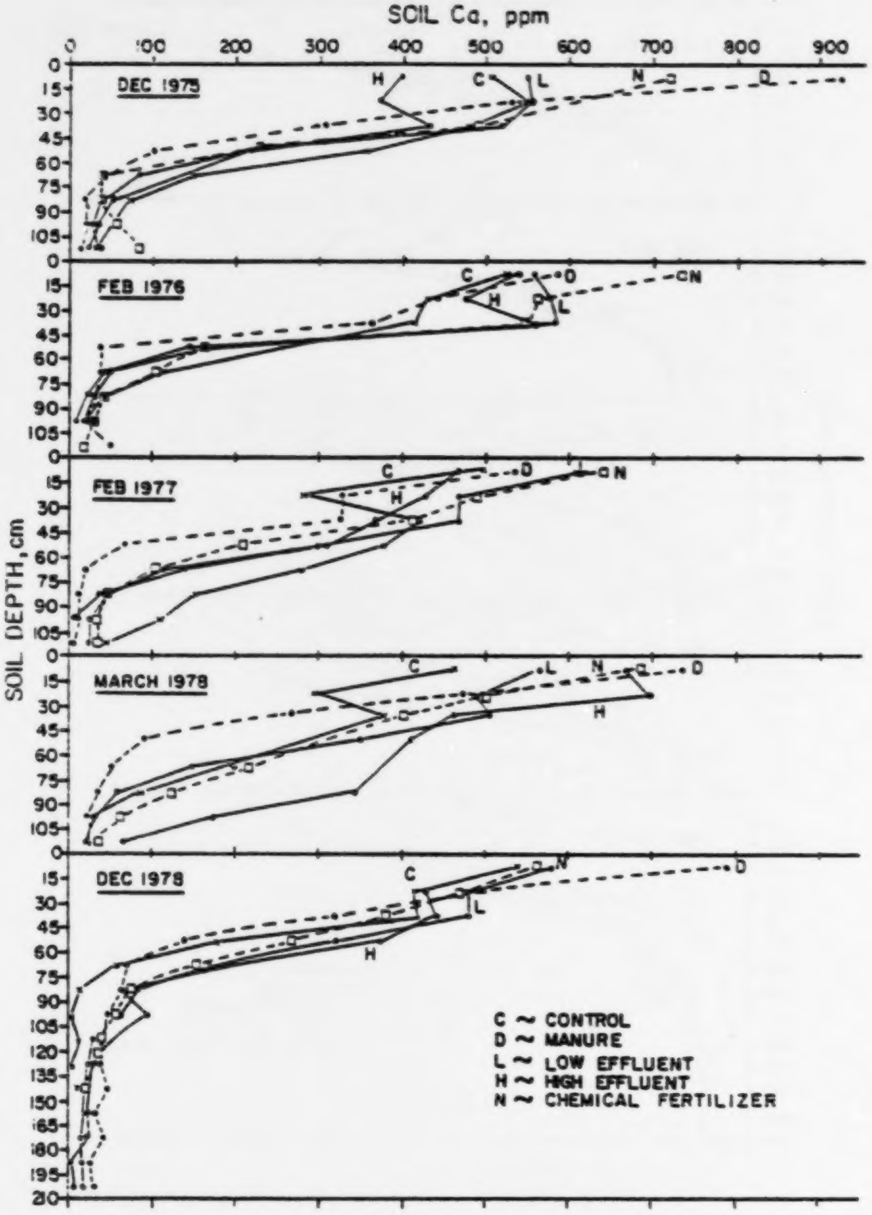

Figure 8. Effect of treatments on dilute acid extractable soil Ca.

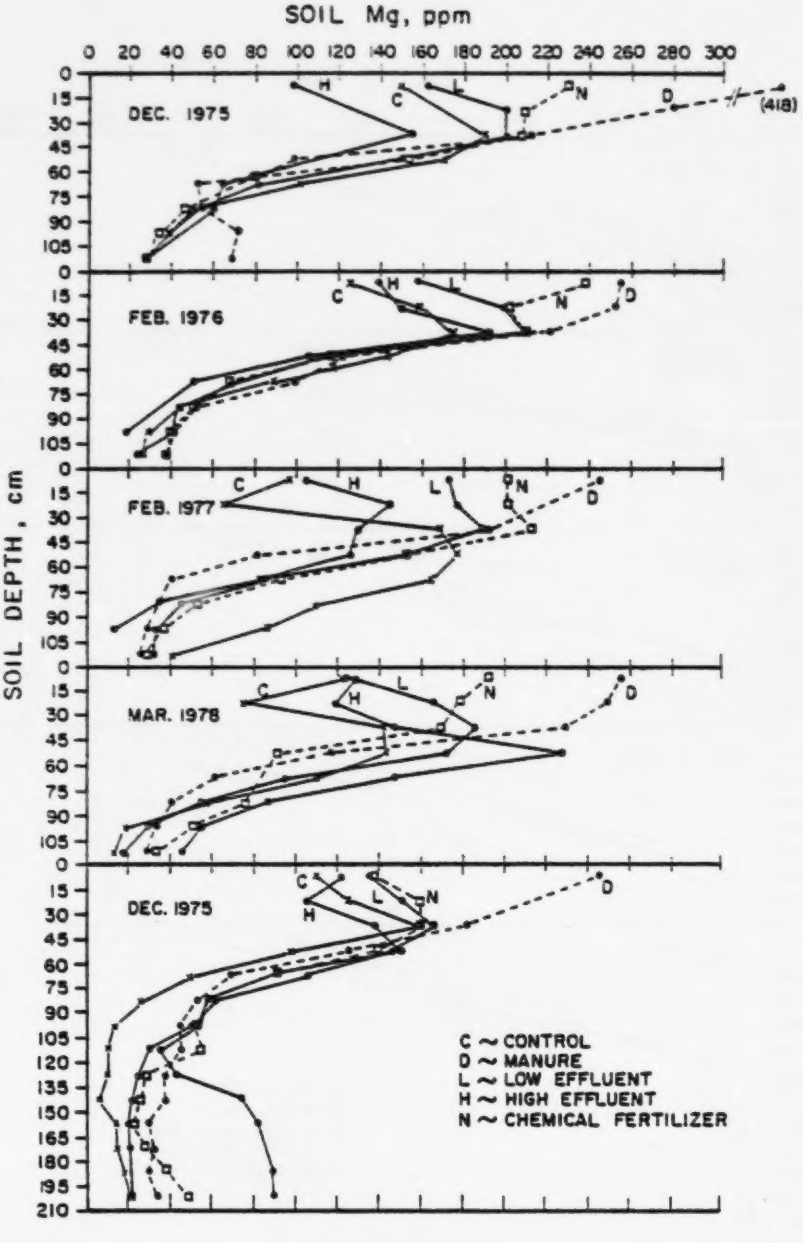

Figure 9. Effect of treatments on dilute acid extractable soil Mg.

rate accumulated in the lower part of the profile. The fertility levels in the 0-15 cm layer in December 1978 were all "very high".

Soil Na

Soil Na concentrations were generally increased by the applied treatments in the following order: control ≈ chemical fertilizer < manure < low effluent rate < high effluent rate (Figure 10). Maximum accumulations occurred in the 30-90 cm soil zone. In December 1978 at the high effluent application rate, Na concentrations in the zone averaged 136 ppm or 0.6 meg/100 g. This is an estimated exchangeable Na percentage of 16% (assuming a CEC of 10) and is about the percentage at which soil dispersion has been noted in soils in the arid areas of the U.S. However, the low pH in this soil zone and the predominance of kaolinitic clay preclude the reduction of hydraulic conductivity by soil dispersion (Hill, 1980).

Soil pH

Manure applications tended to reduce soil pH as compared to pH valves resulting from the other treatments, particularly in the 15-45 cm zone (Figure 11). In March and December 1978, both irrigation rates increased pH in the 0-30 cm zone. At the December 1978 sampling date, the manure and irrigation treatments resulted in soil pH values in the 0-15 cm zone that were within the range recommended for fescue (5.8 - 6.5).

Soil Cu, Zn, and Mn

There was no consistent effect of treatments on soil Cu, Zn or Mn so the data is not presented.

Overall Soil Fertility

All the waste treatments resulted in soil NO_3-N concentrations that were equal to or greater than those resulting from chemical fertilizer additions. Consequently, adequate N was supplied for crop production. The high rate of irrigation and the long-term application of manure pose a groundwater pollution hazard due to excess NO_3-N accumulation in the profile. It appears that the low irrigation rate could also present a groundwater pollution hazard.

A summary of the fertility levels for P, K, Ca and Mg are summarized in Table 25. Manure applications and the low irrigation rate supplied adequate P whereas chemical fertilizer did not supply enough and the high irrigation rate supplied an excessive amount. Continued application of excessive P could result in reduced Fe uptake. However, due to the large amount of Fe in this soil the Fe deficiency would take a long time to develop.

The high application rates of K, Na and N (mostly as NH_3-N) and the relatively low application rates of Ca and Mg (Table 12) with irrigated effluent suggest that a nutrient imbalance may develop. The ratio of cations applied by irrigation expressed as the ratio of equivalent weights applied with all data normalized to Ca were:

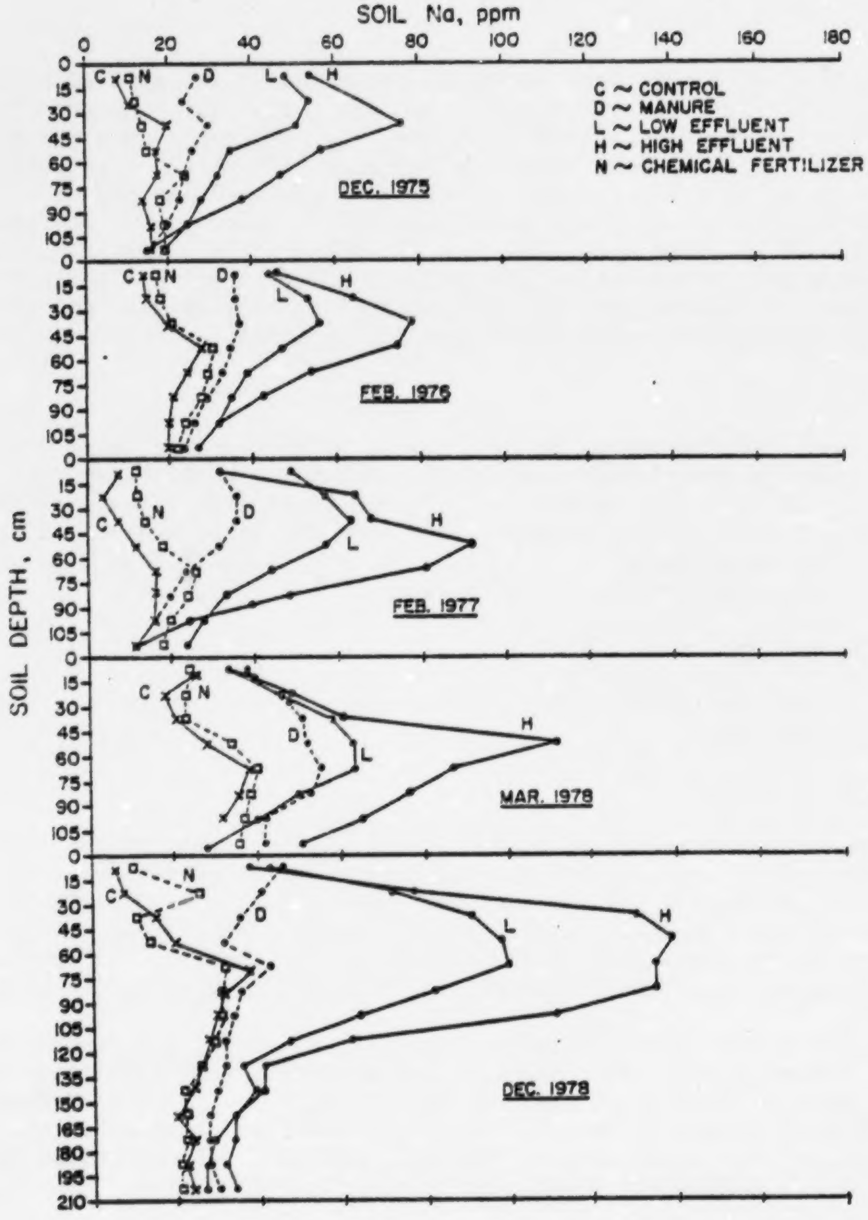

Figure 10. Effect of treatments on dilute acid extractable soil Na.

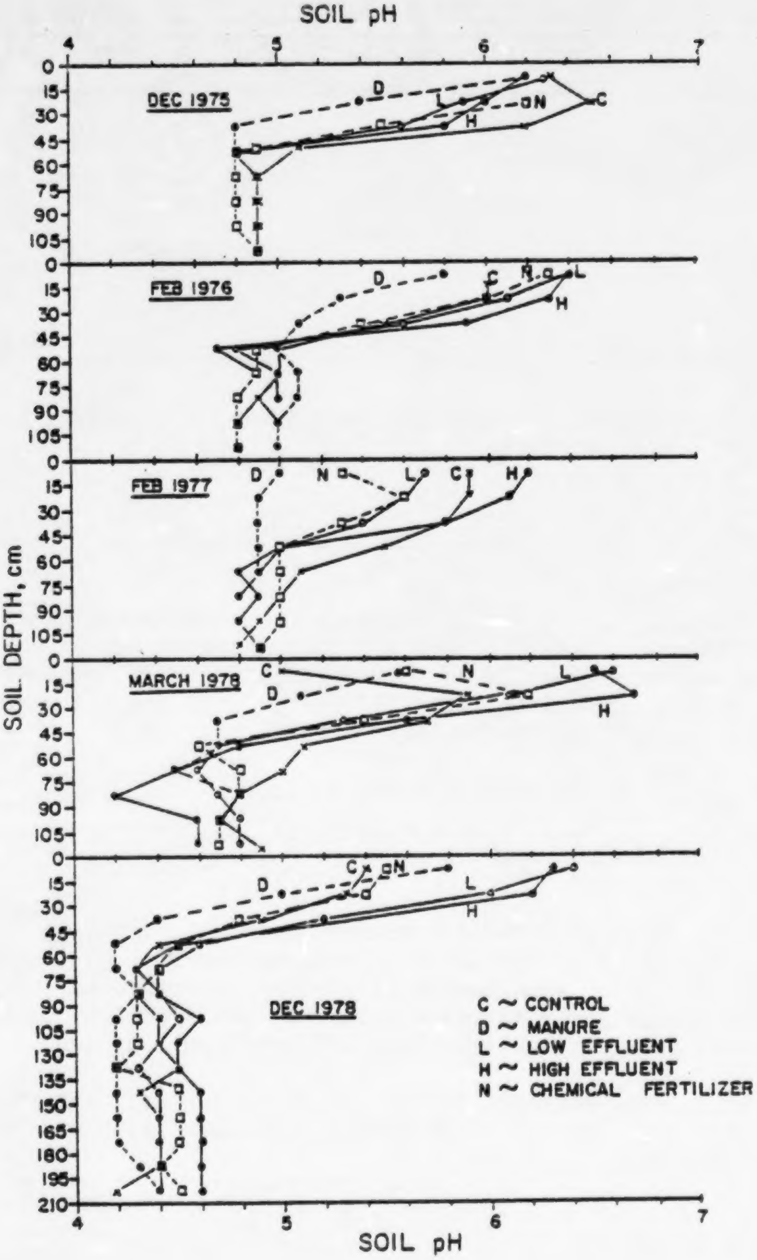

Figure 11. Effect of treatments on soil pH.

TABLE 25. FERTILITY LEVELS FOR P, K, CA AND MG FOR DECEMBER 1978

Nutrient	Fertility level in the 0-15 cm layer of soil			
	Low	Medium	High	Very high
P	C,N*	D	L	H
K		N	C	D,L,H
Ca			C,N,L,H	D
Mg				C,N,D,L,H

*Treatments: C - control, N - chemical fertilizer, D - manure, L - low effluent, and H - high effluent.

Ca^{++}	Mg^{++}	Na^{+}	K^{+}	NH_4^{+}
1	0.7	3.4	4.1	6.2

These ratios suggest that Ca and Mg would be replaced by the other cations and leached downward. However, there was little consistent effect of monovalent cations on leaching of Ca and Mg (Figures 8 and 9), probably because of the high levels of Ca and Mg initially in the soil and the rather high soil buffering capacity due to the clay content (Table 1).

The ratio of cations supplied by manure were:

Ca^{++}	Mg^{++}	Na^{+}	K^{+}	NH_4^{+}
1	0.4	0.3	0.5	1.7

It is evident that lagooning the manure results in settling or precipitation of Ca and Mg such that ratios of Ca + Mg/monovalent cations in the lagoon effluent are low. When manure is applied directly, the Ca and Mg are retained in the manure and a nutrient imbalance would be less likely to occur from manure applications than from effluent applications.

Over the long term, effluent irrigation of lagoon effluent should be supplemented with applications of dolomitic limestone based on a systematic soil testing program.

RAINFALL RUNOFF VOLUMES

Rainfall runoff quantity and quality were evaluated from July 1975 through February 1979 using the various runoff measurement and sampling schemes previously described. Runoff rate and samples with time within a runoff event were obtained on treatments 2-6 during the periods 7/11/75 - 3/25/76 and 9/24/76 - 2/28/78. During the rest of the data period, only one composite sample was collected.

Rainfall runoff volumes were variable from one year to the next. As previously presented in Table 8, annual rainfall was above normal in 1975, below normal in 1976, and about normal in 1977 and 1978. However, if the annual period for rainfall and runoff analysis is designated as March through February, variation between years is less. Also, this period corresponds closely with some periods of different types of samplers. Therefore, the period March to March was used for data analysis except for the first year which includes only July to March.

Rainfall and runoff are presented for the various plots and the four time periods in Table 26. On treatments 1A and 1B, which had a collection barrel throughout the experiment, the barrels overflowed several times. Overflow of collection containers during one short period and equipment malfunctions also occurred on the other six treatments which had various sampling schemes for the different time periods. Also, when rainfall occurred during irrigation, this runoff was not included in rainfall runoff and is reported in the next section. Thus, the rainfall runoff values in Table 26 are not always the total runoff that occurred but generally are greater than 90% of total runoff which occurred, except for treatments 1A and 1B which had overflow several times and also possibly barrel leaks during some periods. Because of the difference in plot size for runoff collection for treatments 1A and 1B compared to the other treatments, and because of excessive missing data or questionable data, treatments 1A and 1B are generally not included in the results.

Rainfall runoff was greatest during the last year (Table 26), but even then the runoff was low compared to expected runoff for this soil, slope and crop cover. Runoff expressed as percent of rainfall was less than 10 percent for the whole period and was above 10 percent for only one period (3/78 - 2/79) for three plots. The high-rate irrigation treatment (treatment 7) had the highest runoff overall. However, there are no other evident trends due to slope or irrigation. For the fertilized treatments, treatment 3 (3-5% slope) usually had greater runoff than treatment 5 (8-10% slope), whereas the opposite was true for the low-rate irrigation treatments with different slopes (treatments 4 and 6). Overall, runoff amount was low for all treatments.

Most of the runoff occurred from a few months with high rainfall or a few large rainfall events. Monthly rainfall and runoff are shown in Appendix Table D-1, while data by event is given in Appendix Table D-2. Months with high rainfall and runoff were July 1975 and April 1978. Other months with relatively high runoff were January 1976, January, March and May in 1978, and January and February in 1979. Runoff was variable between plots for the same month, and differences in annual sums were often due to differences during one or two months during the period.

IRRIGATION OR IRRIGATION-RAINFALL MIXED RUNOFF

Irrigation runoff without any rainfall mixed in occurred only from treatment 7, the high-rate irrigation treatment (Table 27). Runoff amount sometimes seemed high and was probably due to clogged sprinkler nozzles on the

TABLE 26. RAINFALL AND RUNOFF FOR DESIGNATED HYDROLOGIC PERIODS

Period[*]	Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
	--------------------Rainfall runoff, cm--------------------							
7/75 - 2/76	> 4.28[†]	>7.66	5.56	5.77	1.62	3.04	4.69	10.57
3/76 - 2/77	> 7.39	>8.52	2.25[†]	0.81[‡]	0.46[‡]	0.70	0.43	1.02
3/77 - 2/78	>16.34	>18.13	2.67[‡]	>3.94	>2.20	>0.54	>3.16	>3.96
3/78 - 2/79	>24.27	>10.95	13.85[‡]	15.48	8.96[‡]	6.23[‡]	11.18[‡]	17.99[‡]
Total	52.28	45.26	24.33	26.00	13.24	10.51	19.46	33.54
	--------------------Runoff as percent of rainfall, %--------------------							
7/75 - 2/76	> 4.7	> 8.4	6.1	6.3	1.8	3.3	5.1	11.5
3/76 - 2/77	> 6.9	> 7.9	2.5	0.8	0.4	0.6	0.4	1.0
3/77 - 2/78	>13.9	>15.4	2.3	>3.3	>1.9	>0.4	>2.7	>3.4
3/78 - 2/79	>20.8	> 9.4	11.9	13.3	7.7	5.4	9.6	15.4
Mean	11.6	10.3	5.7	5.9	3.0	2.4	4.4	7.8
7/75 - 2/79	>12.1	>10.4	5.6	>6.0	>3.0	>2.4	>4.5	>7.7

[*] Annual period is March through February except first year when data acquisition began July 11, 1975. Rainfall for the four periods were: 91.7 cm, 107.3 cm, 117.8 cm, and 116.4 cm, respectively.

[†] The greater than symbol (>) indicates runoff collector overflowed at least once during the period.

[‡] These values may include estimated runoff amounts for some events, or they may exclude events when the runoff collection system malfunctioned or events when rainfall runoff was mixed with irrigation. See the runoff listed by event in Appendix Table D-2 for further details.

TABLE 27. IRRIGATION RUNOFF VOLUME AND CONCENTRATION[*]

Date	Tmt. #	Runoff, cm[†]	Concentration, mg/ℓ					
			COD	TOC	TKN	NO_3-N	P	Cl^-
751010	7	1.11	-[§]	290	150	1	18	240
17	7	0.20	1200	260	220	18	4	290
24	7	0.57	1200	-	190	4	13	280
31	7	0.42	1300	470	460	5	4	320
1107	7	0.78	1550	-	220	0	13	320
1114	7	0.16	1400	320	220	0	6	290
780428[‡]	7	>0.21	500	80	170	11	26	170
0908	7	0.01	1500	510	220	3	58	290

[*] Treatment 7 (high rate irrigation) was the only irrigated plot which had significant irrigation runoff. All irrigated plots had some rainfall-irrigation mixed runoff which is tabulated separately.

[†] Some runoff volumes seem high and probably resulted from clogged sprinkler nozzles on the end of the plot where the runoff collection gutter was located.

[§] A dash (-) indicates missing value.

[‡] Rainfall runoff occurred 780427 and the wet conditions likely caused this irrigation event to have lower concentrations. The sampler malfunctioned and runoff amount was estimated from the sample volume.

end of the plot where the runoff collection gutter was located. Concentrations of nutrients in irrigation runoff were lower than the irrigated effluent concentrations but were still very high. Most irrigation events occurred within two days after a rainfall event or during a rainy period. If irrigation had been delayed when soil moisture was high, then runoff from irrigation could have been greatly reduced. However, the weekly irrigation application was normally not adjusted because of rainfall.

Irrigation-rainfall mixed runoff occurred a few times. Of the treatments 2-7, only treatment 7 had any significant runoff events (Table 28). Again, clogging of irrigation nozzles near the runoff collection gutter could have occurred for some of these events. The nutrient concentrations were variable but were generally high compared to rainfall runoff. If the irrigation schedule had been adjusted when rain was predicted, the number of irrigation events with rainfall also occurring may have been reduced. However, the number of irrigation events with runoff was still relatively low without adjusting the schedule for rain prediction.

The mass transport of nutrients in the irrigation runoff or irrigation rainfall mixed runoff is shown in Table 29. In 1975, the amount of N in irrigation runoff from treatment 7 was about 5% of the amount applied. Other than this, the nutrient transport was very small compared to what was applied.

Overall, few runoff events resulted directly from irrigation, or irrigation which occurred during a rainfall event. However, runoff of this type had very high nutrient concentrations and should be avoided by adjusting the irrigation schedule based on soil moisture and weather forecasts.

CONCENTRATIONS IN RUNOFF

Concentrations were highly variable depending upon factors such as rainfall and runoff amounts, time of year, and whether nutrients had been recently applied. The volume-weighted concentrations were calculated by determining total mass of nutrients transported and dividing by total runoff volume for the time period of concern including only those events which had both runoff volume data and concentration data. However there was very little missing data, and almost all of it occurred during July-September 1975.

Mean Concentrations Over Entire Period

Mean concentrations of selected nutrients are presented as volume-weighted means for each runoff period in Table 30. For several parameters, the treatment with the highest concentration each year was the high-rate irrigation treatment (treatment 7). However, this was not always the case. If another treatment had a higher mean concentration, it was usually a fertilizer treatment or the manure treatment, which was typically the result of a significant runoff event after a fertilizer or manure application. For example, in 1977 treatment 5 (fertilizer) and treatment 2 (manure) had the highest mean concentrations. For treatment 5, a fertilizer application was

TABLE 28. RAINFALL --IRRIGATION MIXED RUNOFF

Date	Tmt. #	Runoff, cm	Rainfall, cm	Concentration, mg/ℓ							
				COD	TOC	TKN	NH_3-N	NO_3-N	P	OP	Cl^-
750926	7	0.93	0.96	330	-*	46	-	14	19	-	-
760604	1B	0.22	1.09	650	140	65	-	8.2	8.2	-	90
04	4	0.02		30	14	10	-	1.0	1.4	-	14
780412	7	0.08	0.25	1200	330	64	12	0	58	50	690
780505	1A	0.21	0.43	500	130	121	120	0	24	22	140
05	1B	0.28		-	-	-	-	-	-	-	-
05	7	0.32		630	350	173	166	3.0	34	29	185
780609	1A	0.03	4.57	250	70	18	9	25	6.6	6.1	80
09	4	0.01		110	40	18	15	2.0	6.6	6.6	35
09	6	0.01		70	20	6.3	1.7	5.3	1.3	0.8	10
09	7	0.32		340	100	61	51	6.4	16	15	90
780901	7	0.02	1.02	1400	430	216	93	-	47	28	240

*A dash (-) indicates missing data.

TABLE 29. MASS IN RUNOFF FROM IRRIGATION AND RAINFALL - IRRIGATION MIXED

Date	Tmt. #	Runoff, cm	Runoff type[§]	Mass in runoff, kg/ha TOC	TKN	NO_3-N	N	P	Cl^-
750926	7	0.93	R + I	-[*]	4.3	1.3	5.6	1.8	-
1010	7	1.11	I	32.2	16.6	0.1	16.7	2.0	26.6
1017	7	0.20	I	5.2	4.4	0.4	4.8	0.1	5.8
1024	7	0.57	I	-	10.8	0.2	11.0	0.7	16.0
1031	7	0.42	I	19.7	19.3	0.2	19.5	0.2	13.4
1107	7	0.78	I	-	17.2	0.0	17.2	1.0	25.0
1114	7	0.16	I	5.1	3.5	0.0	3.5	0.1	4.6
760604	1B	0.22	R + I	3.1	1.4	0.2	1.6	0.2	2.0
04	4	0.02	R + I	0.0	0.0	0.0	0.0	0.0	0.0
780412	7	0.08	R + I	2.6	0.5	0.0	0.5	0.5	5.5
0428	7	>0.21[†]	I	1.7	3.6	0.2	3.8	0.5	3.6
0505	1A	0.21	R + I	2.7	2.5	0.0	2.5	0.5	2.9
05	1B	0.28	R + I	-	-	-	-	-	-
05	7	0.32	R + I	11.2	5.5	0.1	5.6	1.1	5.9
0609	1A	0.03	R + I	0.2	0.0	0.1	0.1	0.0	0.2
09	4	0.01	R + I	0.0	0.0	0.0	0.0	0.0	0.0
09	6	0.01	R + I	0.0	0.0	0.0	0.0	0.0	0.0
09	7	0.32	R + I	3.2	2.0	0.2	2.2	0.5	2.9
0901	7	0.02	R + I	0.9	0.4	-	-	0.1	0.5
0908	7	0.01	I	0.5	0.2	0.0	0.2	0.1	0.3

[§] R + I indicates rainfall-irrigation mixed runoff; I indicates irrigation runoff.

[*] Dash (-) indicates missing data.

[†] Sampler on treatment 7 malfunctioned after 0.21 cm runoff.

TABLE 30. VOLUME-WEIGHTED CONCENTRATION IN RAINFALL RUNOFF

		Volume-weighted concentration, mg/ℓ*				
		Runoff year§				
Tmt. type	Tmt. no.	1975	1976	1977	1978	Entire period
TKN						
Fert.	3	5.9	3.0	2.9	3.1	3.7
Fert.	5	12.3	6.4	19.7	3.0	6.7
Low irg.	4	7.7	5.3	3.1	3.9	4.3
Low irg.	6	3.9	6.0	5.6	3.8	4.2
High irg.	7	6.2	23.4	8.2	5.7	6.7
Manure	2	5.9	4.3	19.6	7.0	7.8
NO_3-N						
Fert.	3	3.1	1.2	1.5	2.7	2.5
Fert.	5	3.0	4.2	15.2	1.3	2.7
Low irg.	4	6.1	3.4	7.2	2.2	3.6
Low irg.	6	8.2	3.2	4.2	2.6	4.2
High irg.	7	18.1	10.6	16.6	7.4	12.0
Manure	2	4.7	10.6	7.9	6.1	6.6
N‡						
Fert.	3	9.2	3.9	4.4	5.7	6.2
Fert.	5	16.4	10.5	34.9	4.4	9.5
Low irg.	4	13.8	8.7	10.3	6.1	7.8
Low irg.	6	12.1	9.2	9.8	6.4	8.3
High irg.	7	24.4	32.3	24.8	13.2	18.7
Manure	2	11.7	14.5	27.5	13.1	14.9
Cl^-						
Fert.	3	6.3	5.4	4.6	4.2	4.6
Fert.	5	13.9	14.8	23.4	3.0	7.3
Low irg.	4	16.1	13.1	14.0	8.0	10.0
Low irg.	6	8.8	22.9	12.7	8.8	9.8
High irg.	7	46.9	12.5	29.0	9.9	18.2
Manure	2	10.4	7.7	21.0	6.2	8.6
P						
Fert.	3	0.8	0.7	1.0	0.6	0.7
Fert.	5	2.2	1.2	4.3	0.6	1.3
Low irg.	4	1.5	1.1	2.9	1.3	1.6
Low irg.	6	1.1	1.6	1.9	1.8	1.6
High irg.	7	13.9	6.2	4.6	6.2	7.1
Manure	2	1.6	4.5	10.2	6.0	6.0

(continued)

TABLE 30. (continued)

Tmt. type	Tmt. no.	Volume-weighted concentration, mg/ℓ[*]				
		Runoff year[§]				Entire period
		1975	1976	1977	1978	
		TOC				
Fert.	3	29	17	18	21	22
Fert.	5	36	22	49	19	24
Low irg.	4	42	26	16	22	23
Low irg.	6	27	60	32	26	28
High irg.	7	51	54	36	31	37
Manure	2	31	33	69	26	33
		COD				
Fert.	3	63	41	70	52	56
Fert.	5	104	61	183	46	67
Low irg.	4	108	81	89	56	69
Low irg.	6	92	175	107	60	73
High irg.	7	130	202	123	71	89
Manure	2	91	70	217	63	87

[*] Missing data occurred for both rainfall runoff volume and concentration. Most of the concentration missing data was for Cl^- and P in July, 1975. Runoff missing data can be observed from Appendix Table D-2.

[§] Runoff year was March through February except for 1975 when data began July 1975.

[#] If either TKN or NO_3-N was missing, then N was considered missing.

made on September 6 and the runoff event of September 8 had TKN and NO_3-N concentrations of 54.1 mg/ℓ and 61.1 mg/ℓ, respectively, for a runoff volume of 0.08 cm. The effect of a manure application was evident in 1977 when 1.38 cm of runoff from treatment 2 had TKN, P, and Cl^- concentrations of 32, 17, and 38 mg/ℓ, respectively, for the March 13 event which was 5 days after a manure application. Thus, where fertilizer or manure are surface applied and readily available for runoff, high concentrations can result if rainfall runoff occurs within a few days after application.

The volume-weighted mean concentrations for the entire period show the high-rate irrigation treatment (treatment 7) and the manure treatment (treatment 2) to have the highest N and P concentrations. This is evident in Figures 12 and 13. The high NO_3-N concentration for the high-rate irrigation treatment is also evident. There are no obvious differences in concentrations between the fertilized plots and the irrigated treatments applying 600 kg N/ha except the irrigated treatments have slightly higher NO_3-N, Cl^- and P concentrations.

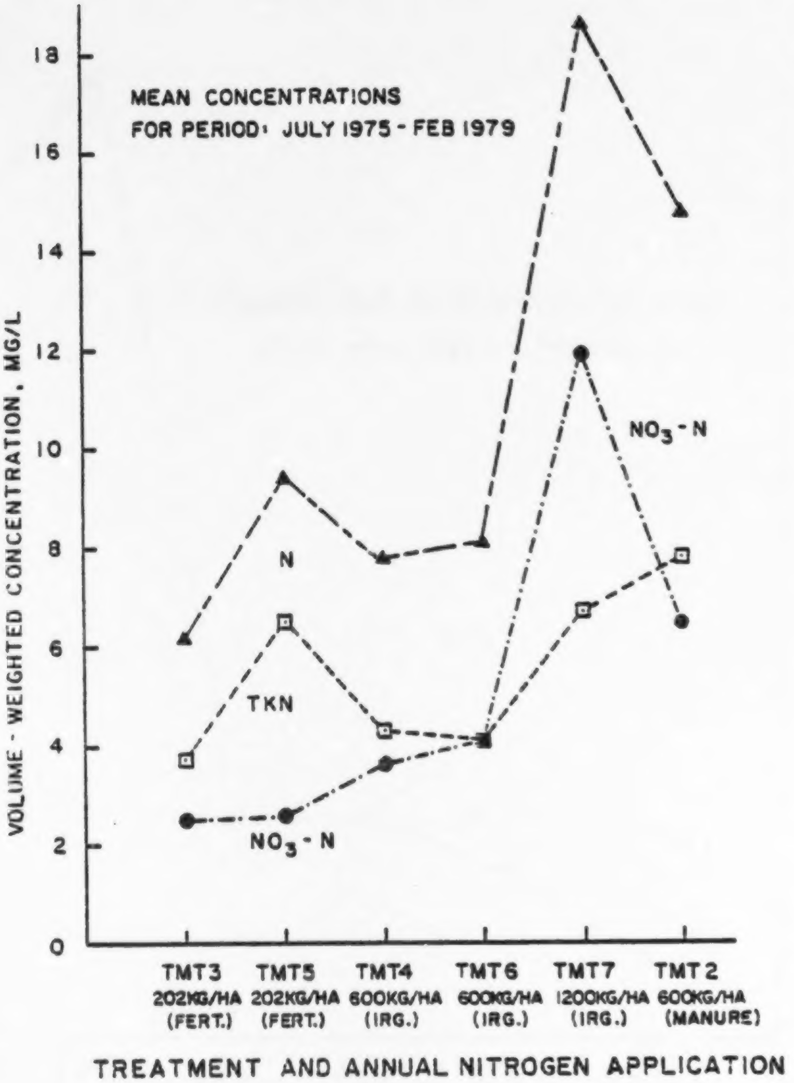

Figure 12. Effect of treatments on mean concentrations of N, TKN and NO_3-N in rainfall runoff for entire period.

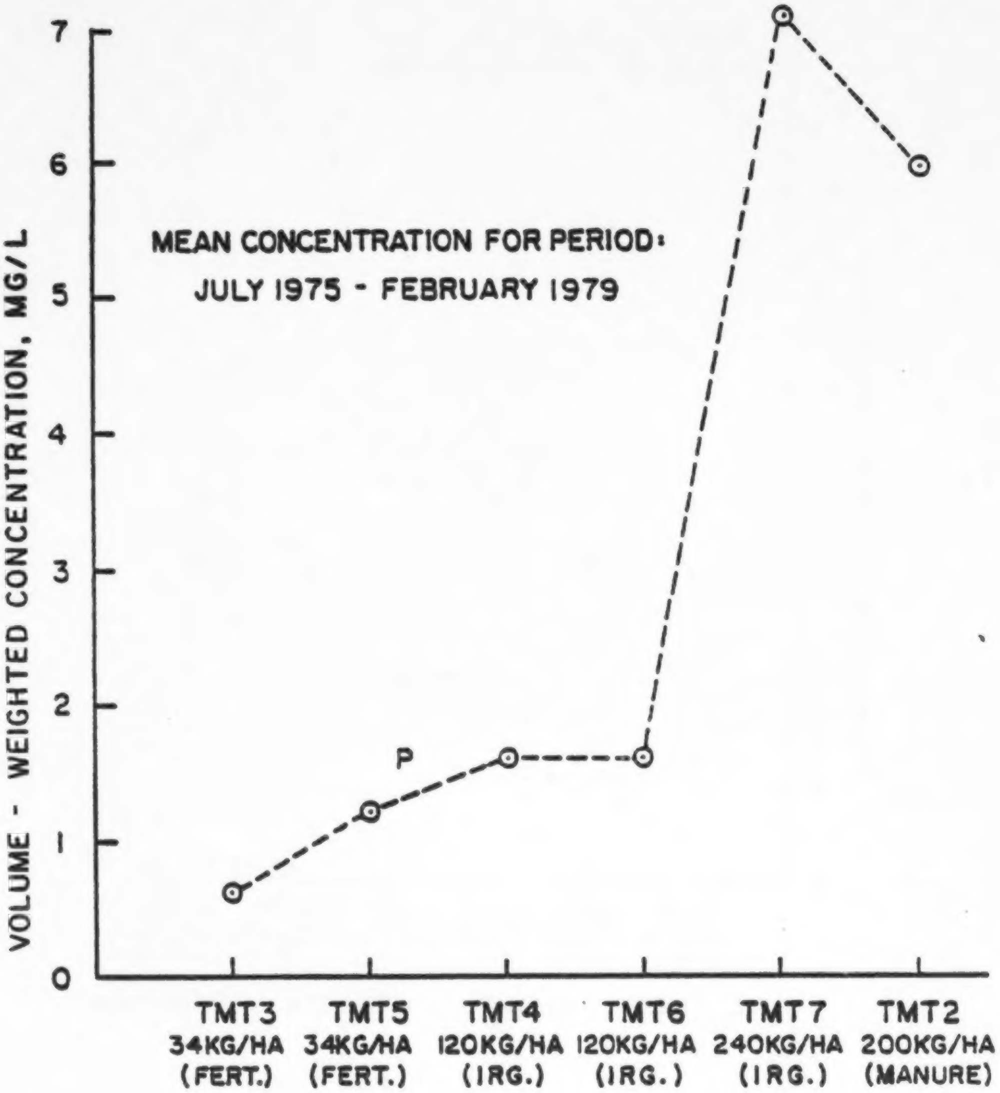

Figure 13. Effect of treatments on mean concentration of P in rainfall runoff for entire period.

Mean Concentrations for March 1978 - February 1979

The annual period with the most runoff was March 1978 - February 1979 when the tipping bucket sampler was used. For this period of data, the arithmetic means and standard deviations of the runoff event concentrations were calculated (Table 31). The arithmetic means are normally higher than the volume-weighted means for all of the nutrients or organic indicators measured, which indicates that events with larger runoff volume tended to have lower concentrations. The standard deviation is often about equal to the mean, and this indicates a large variation in concentration for different events. The monthly summaries of runoff, mean and highest concentrations for TKN, P, NO_3-N and N are presented in Appendix Tables D-3 through D-6 and indicate the variations from month to month.

The relative treatment effects on volume-weighted concentrations for this 1-yr period were similar to the differences averaged over the four periods. The fertilizer treatments and low-rate irrigation treatments had similar volume-weighted N concentrations while the high-rate irrigation and manure treatments had much higher concentrations of NO_3-N and TKN (Figure 14). The NO_3-N and TKN values for this period were lower than the mean values for the 44-month period. For P and OP, the concentrations increased as the amount of P applied increased (Figure 15). Most of the P was in the OP form, and the P values for this period were very similar to the mean values for 44-month period. Overall, the nutrient concentrations in runoff were much higher for the manure and high-rate irrigation treatments compared to the fertilizer and low-rate irrigation treatments. The environmental effect of these highest concentrations would depend upon the amount of flow and nutrients that reached a receiver stream or reservoir and the flow and nutrient levels of the receiver stream or reservoir. The runoff volumes from these plots were low; thus, the mass transport (presented later) may be low even though concentrations are high.

Another consideration for determining environmental impact of the runoff is the maximum concentration. Maximum concentrations and associated runoff volumes for events during the period March 1978 through February 1979 are shown for several nutrients in Table 32. Usually the highest concentration is associated with very low runoff volume. However, there are some exceptions. For the manure treatment (treatment 2) the highest concentrations of TKN, NH_3-N, P and OP occurred with high volumes of runoff. For NH_3-N, the highest concentration occurred with 3.27 cm of runoff on 4-26-78 which was six days after a manure application. A similar situation resulted for treatment 3 (fertilizer) when the highest concentration of NO_3-N occurred for a runoff volume of 4.0 cm on 4-26-78 which was 6 days after a fertilizer application. The highest P and OP concentrations on treatment 2 occurred on 12-5-78, and a manure application had occurred on 11-14-78. The other events with high runoff volume and concentration occurred with the high-rate irrigation treatment, particularly on 11-8-78 which was during the last week of irrigation. Overall, the largest concern for a single runoff event would probably be when a large rainfall event occurred soon after a manure or fertilizer application or if rainfall occurred during irrigation.

TABLE 31. MEAN CONCENTRATIONS IN RAINFALL RUNOFF FOR MARCH 1978 - FEB. 1979

Tmt. type	Tmt. no.	TKN			NH_3-N			NO_3-N		
		M_{vw}*	M_A*	σ*	M_{vw}	M_A	σ	M_{vw}	M_A	σ
Fert.	3	3.1	3.5	2.3	0.70	0.88	0.72	2.7	1.6	1.4
Fert.	5	3.0	4.4	3.6	0.71	1.52	1.64	1.3	2.6	2.4
Low irg.	4	3.9	6.0	4.4	0.41	1.35	1.92	2.2	4.9	4.1
Low irg.	6	3.8	7.4	7.7	0.65	2.68	4.43	2.6	4.5	4.0
High irg.	7	5.7	7.3	3.6	0.72	1.43	1.51	7.4	8.5	6.8
Manure	2	7.0	5.2	5.0	1.59	0.96	0.98	6.1	4.8	4.1
		N			P			OP		
Fert.	3	5.7	5.1	3.0	0.64	0.58	0.47	0.49	0.24	0.31
Fert.	5	4.4	7.0	5.4	0.64	1.04	1.15	0.56	0.72	0.86
Low irg.	4	6.1	11.0	7.7	1.28	2.62	3.52	1.25	2.48	3.05
Low irg.	6	6.4	11.9	10.9	1.75	2.85	3.26	1.63	2.54	2.93
High irg.	7	13.2	15.7	9.2	6.20	6.38	4.12	6.35	6.15	3.90
Manure	2	13.1	10.1	7.0	6.03	3.45	3.50	5.46	3.02	3.26
		COD			TOC			Cl^-		
Fert.	3	52	62	60	20.9	21	11	4.2	5.0	5.8
Fert.	5	46	61	50	18.7	25	21	3.0	6.2	8.3
Low irg.	4	56	91	65	21.9	32	21	8.0	21.9	27.4
Low irg.	6	60	86	86	25.7	37	34	8.8	14.9	14.0
High irg.	7	71	91	41	30.9	35	12	9.9	13.4	10.4
Manure	2	63	59	28	26.4	23	11	6.2	5.9	4.8

*M_{vw} = volume-weighted mean concentration; M_A = arithmetic mean concentration for all events, and σ = standard deviation for event concentrations.

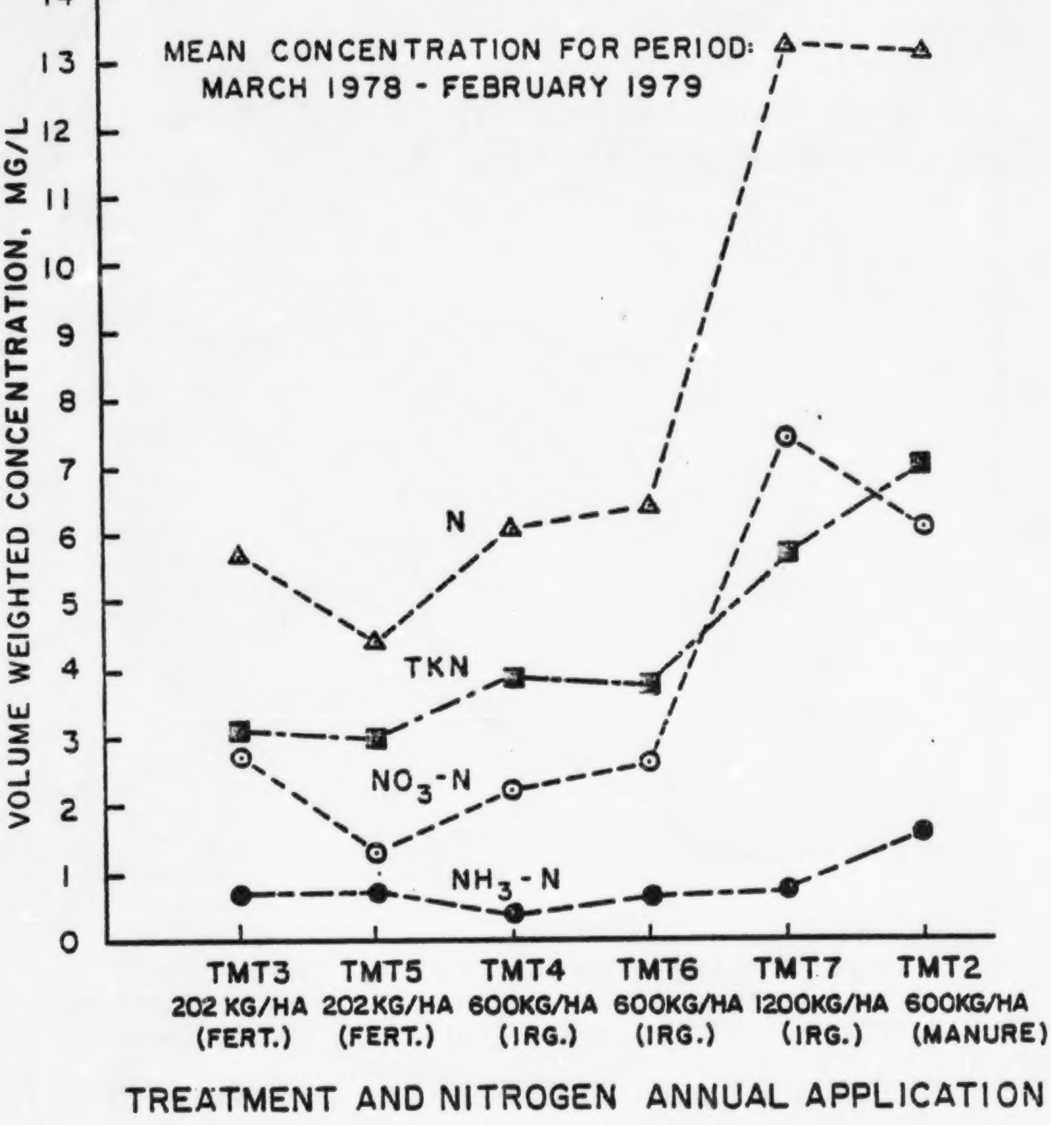

Figure 14. Effect of treatments on mean concentrations of N, TKN, NO_3-N and NH_3-N in rainfall runoff for fourth year (3/78 - 2/79).

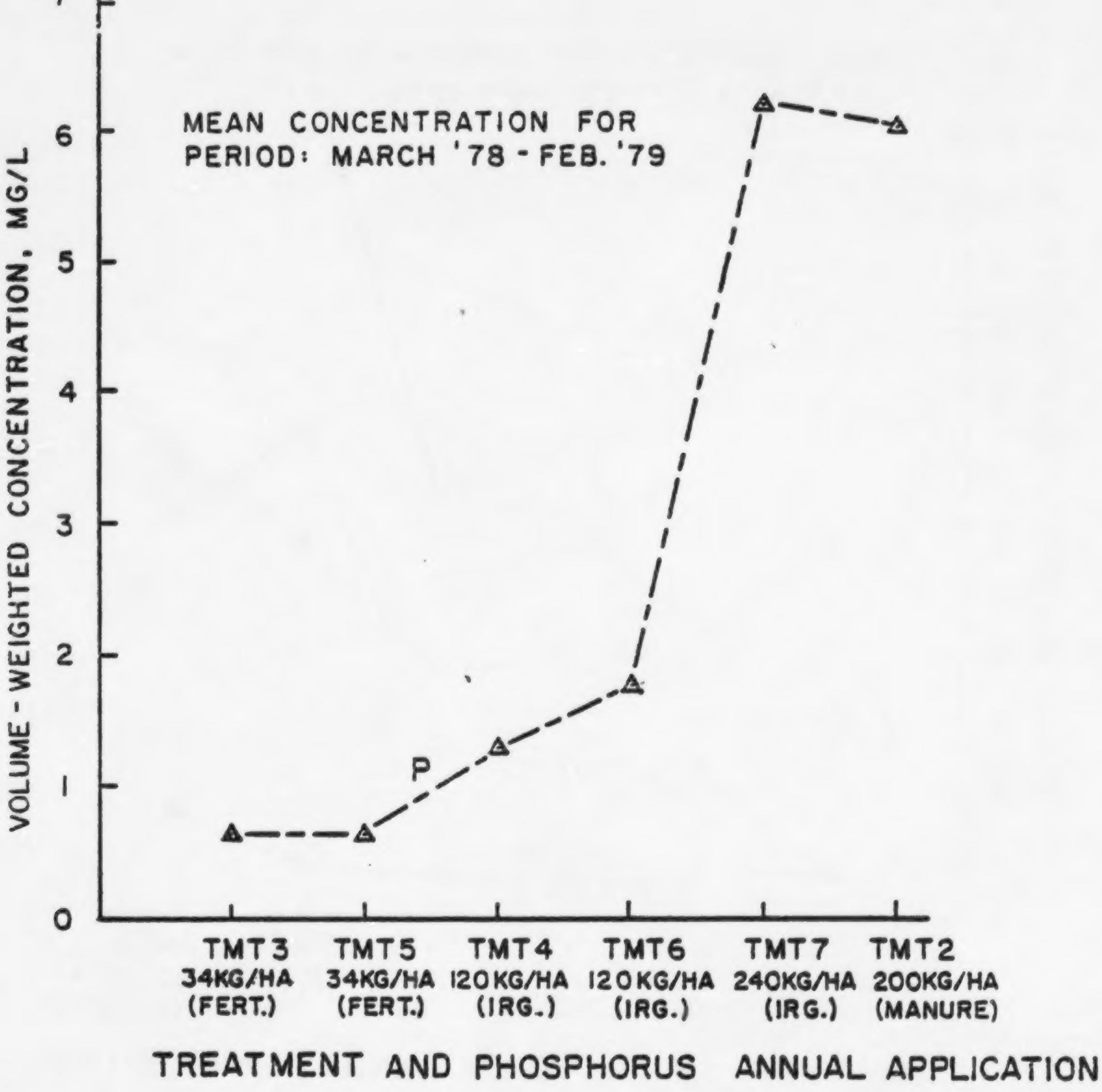

Figure 15. Effect of treatments on mean concentration of P in rainfall runoff for fourth year (3/78 - 2/79).

TABLE 32. HIGHEST CONCENTRATIONS IN RUNOFF FOR MARCH 1978 - FEB. 1979

		TKN			NH_3-N			NO_3-N		
Tmt. type	Tmt. no.	Conc., mg/ℓ	Date	Vol., cm	Conc., mg/ℓ	Date	Vol., cm	Conc., mg/ℓ	Date	Vol., cm
Fert.	3	11.7	4-12	0.01	3.9	4-12	0.01	8.4	4-26	4.00
Fert.	5	18.4	7-11	0.03	7.9	9-11	0.06	11.9	9-11	0.06
Low irg.	4	22.0	7-15	0.01	7.5	7-15	0.01	16.4	3-6	0.01
Low irg.	6	36.0	10-1	0.02	13.8	10-1	0.02	16.9	10-1	0.02
High irg.	7	17.9	5-15	0.01	5.2	10-1	0.05	32.3	11-8	0.69
Manure	2	26.4	2-24	0.78	4.2	4-26	3.27	15.7	3-13	0.02
		P			OP			Cl^-		
Fert.	3	2.7	4-27	0.10	1.6	2-23	0.51	26.0	5-15	0.01
Fert.	5	5.3	9-1	0.04	4.2	9-1	0.04	33.0	9-1	0.04
Low irg.	4	16.8	7-15	0.01	13.5	7-15	0.01	126.0	7-15	0.01
Low irg.	6	15.4	10-1	0.02	12.5	10-1	0.02	70.0	10-1	0.02
High irg.	7	18.8	11-8	0.69	18.4	11-8	0.69	47.0	3-27	0.11
Manure	2	14.5	12-5	0.96	10.5	12-5	0.96	19.0	4-27	0.06

VARIATION OF RUNOFF RATE AND CONCENTRATION WITHIN AN EVENT

Two events with relatively high runoff volume and concentrations were chosen to illustrate the variation in runoff rate and concentration within an event. The manure treatment (treatment 2) and two runoff events in 1977 were chosen.

The rainfall and runoff for the two events are shown in Figure 16. One event occurred on 1/9/77 and 1/10/77 and had low to moderate intensity over a 17-hr period, whereas the other event (3/13/77) had moderate intensity over a 7.5-hr period. The runoff rate was determined only the first 4 hours after runoff began because the rotating distribution arm of the sampler completed the rotation over 33 jars in 4 hours and the remaining runoff sample went into a composite sample to help determine total runoff.

Rainfall intensity, runoff rate and concentrations of P, TKN, NO_3-N and N for various time intervals during the 1/9/77 event are shown in Figure 17. The runoff rate shows some direct correlation to rain intensity with a slight time lag in runoff response to changes in rain intensity. When a runoff collection jar had less than 100 ml, it was composited with following jars until at least 150 ml total volume was obtained. Thus, the concentration data reflects some composite samples. The concentration values show some variation, but there is not much decrease in concentration when the composite sample concentration representing 0.82 cm of runoff is compared to the concentration at the end of the first four hours or even compared to the average concentration for the 0.29 cm runoff which occurred during the first 4 hours. There does not appear to be a large initial flush of nutrients from the plots, but the slow to moderate rainfall intensity and runoff rate tend to cause the concentration in runoff to remain within a fairly narrow range. The nutrient level on the plot was probably moderately high because manure was applied 11/9/76 and only 1.04 cm of runoff had occurred from then until the 1/9/77 event. This could indicate that much more runoff would have to occur before concentrations would substantially decrease. The next runoff event was 3/7/77 and had 1.02 cm of runoff with average concentrations of 6.6 mg/ℓ for TKN, 7.7 mg/ℓ for NO_3-N, 15.77 mg/ℓ for N and 1.28 mg/ℓ for P, which are similar to the average concentrations for the 1/9/77 event, with only P being reduced. This indicates that the nutrient level on the plot had remained high.

Manure was applied to treatment 2 on 3/8/77 and a rainfall event of 4.39 cm occurred on 3/13/77 which resulted in 1.38 cm of runoff. Since it had also rained 1.55 cm on 3/5/77 and 3.30 cm on 3/7/77, this event had high potential for runoff and transport of the applied manure.

Plots of rain intensity, runoff rate and concentration in Figure 18 demonstrate some correlation between these three parameters. Rain intensity was variable and the runoff rate was also variable while showing a slight time lag in responding to changes in rain intensity. The concentrations of the four nutrients shown in Figure 18 all increased during the first 15 to 30 min. of the runoff event and then showed variation with some response to runoff rate and particularly rain intensity. After an intense period of rain the concentrations seemed to increase except for NO_3-N in one case.

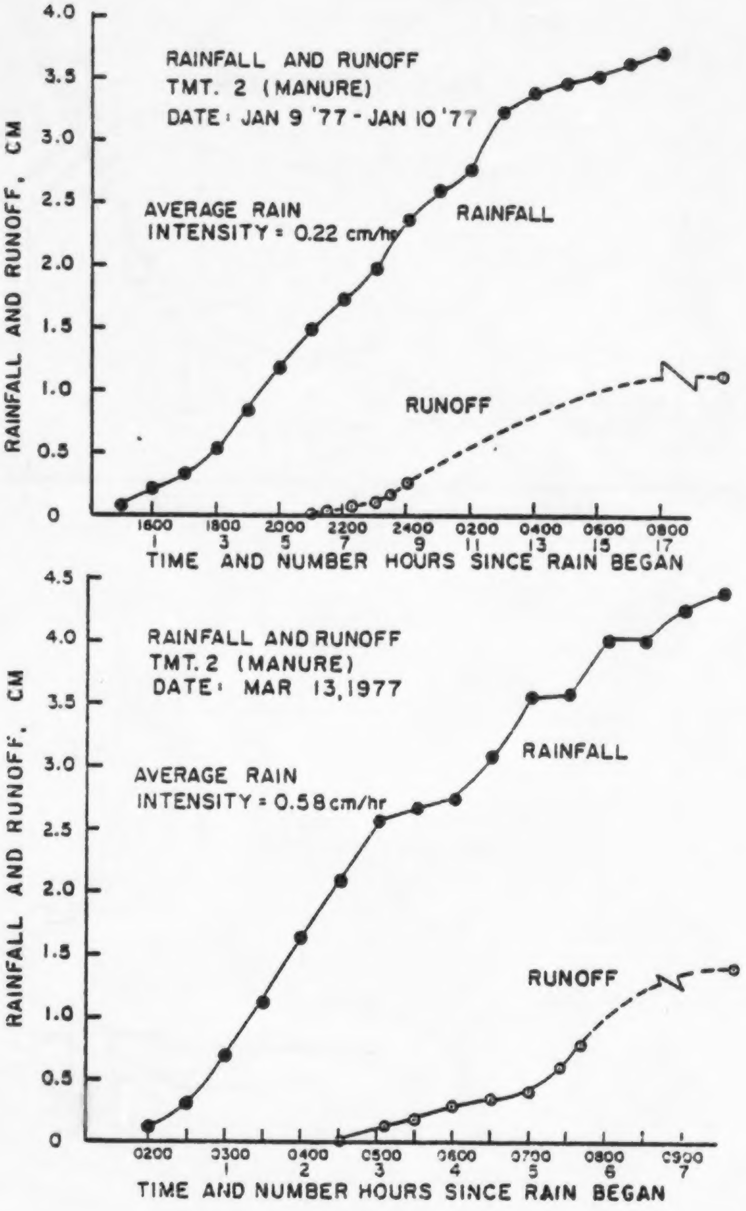

Figure 16. Rainfall and runoff for two selected events on the manure treatment.

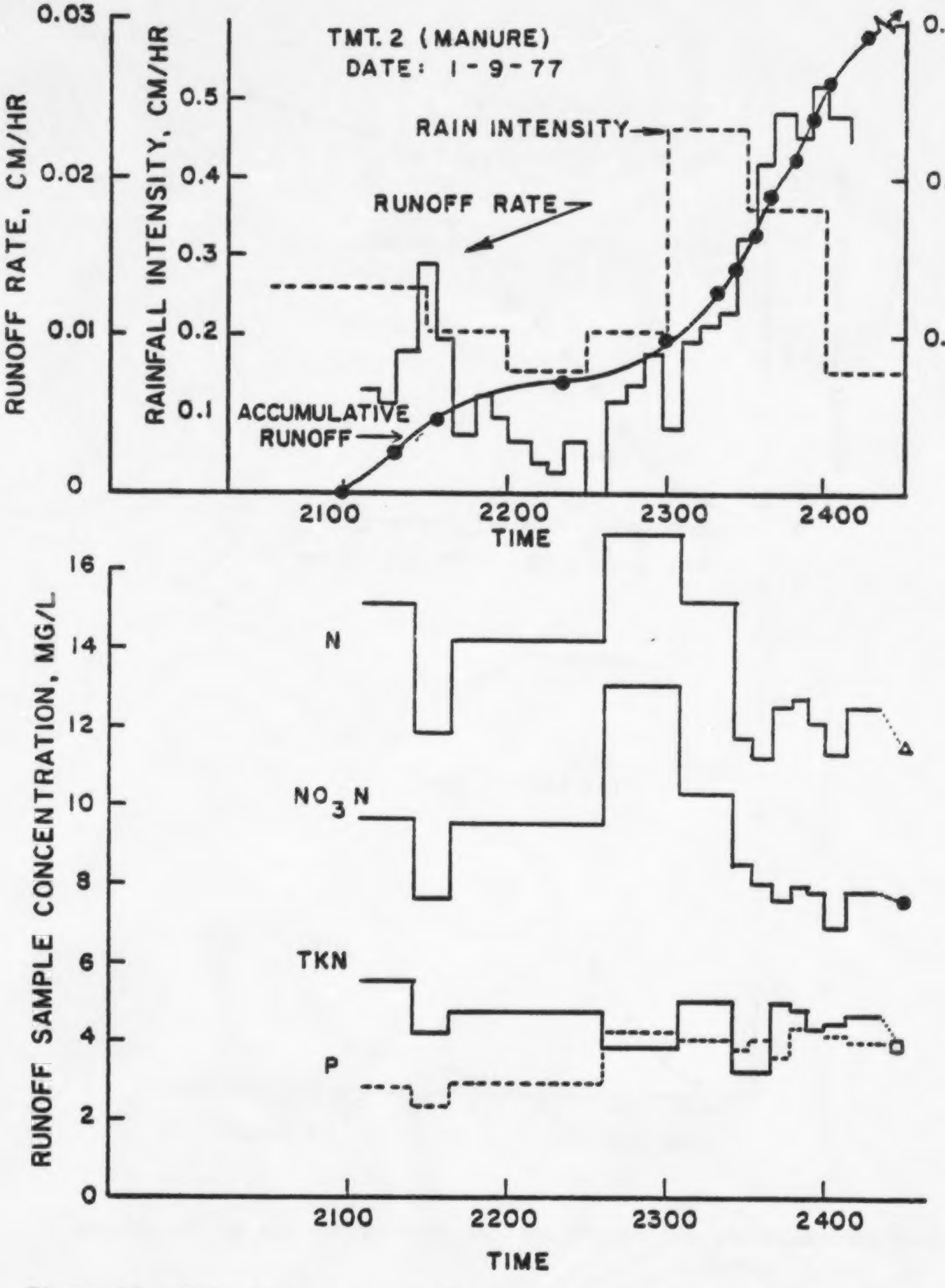

Figure 17. Rain intensity, runoff rate and nutrient concentrations in runoff for event on 1-9-77 and 1-10-77.

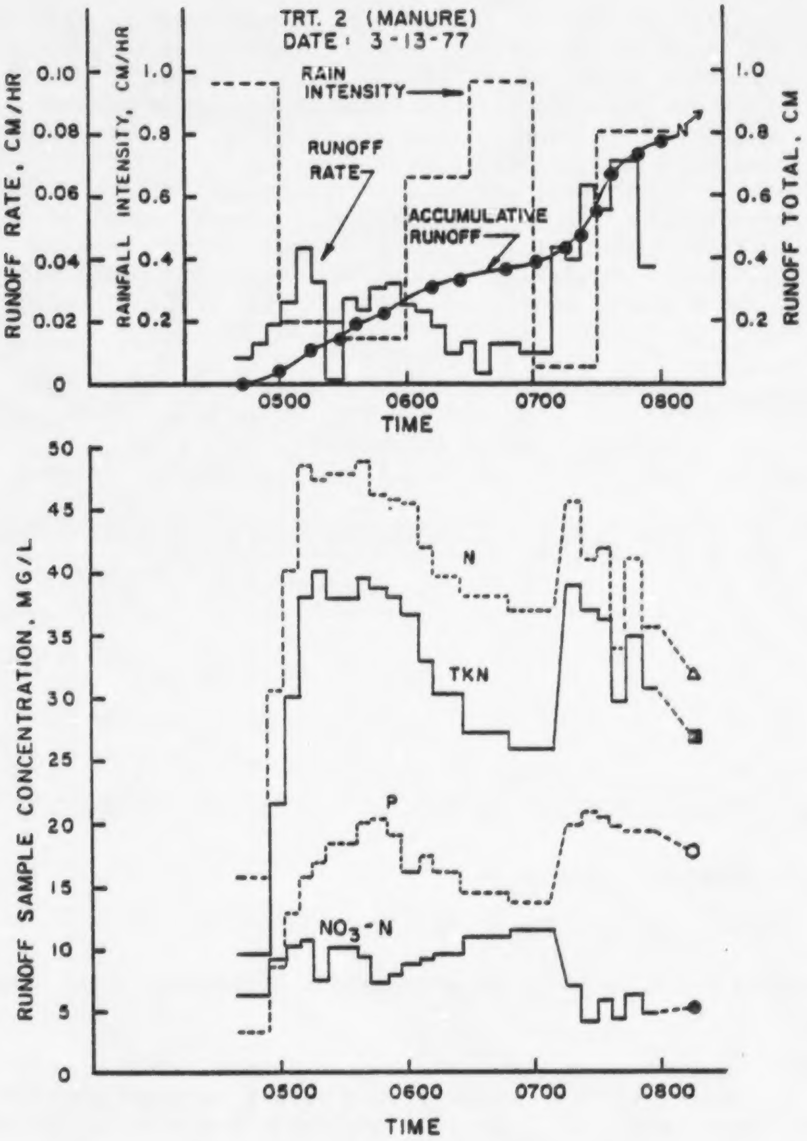

Figure 18. Rain intensity, runoff rate and nutrient concentration in runoff for event on 3-13-77.

Trends of concentration variation and corresponding amount of runoff for each concentration value are shown in Figure 19 and 20 for the two events. These graphs do not indicate which samples were composited. Both events show variation in concentration during the event, and a trend of increasing concentration and then decreasing concentration is particularly evident with TKN and P for the 3/13/77 event. This seems to indicate that transport of nutrients increased during the initial phases of runoff, and then perhaps after the most readily available or easily detachable material was removed, the concentrations decreased to somewhat steady-state. The trend of increasing and then decreasing concentration was not prevalent in most other events, and is likely a characteristic of this particular circumstance which was a variable-rate runoff event soon after a manure application. For most events, the concentrations were variable within relatively small ranges for a particular event and plot, but the variation from one event to another or between plots could be relatively large, as occurred in the examples given for treatment 2.

The average concentrations for the runoff event just after manure application and for the two most previous events are shown in Table 33. The effect of the manure application is obvious. This illustrates the need to consider weather forecasts before surface application of manure.

TABLE 33. EFFECT OF MANURE APPLICATION ON CONCENTRATIONS IN RUNOFF[*]

	Rainfall,[†]	Runoff,	Mean concentration, mg/ℓ[‡]				
Date	cm	cm	TKN	NO_3-N	N	P	Cl^-
1/9/77	3.76	1.11	4.4	8.6	13.0	3.7	7.2
3/7/77	3.30	1.02	6.6	7.7	14.3	1.3	5.8
3/13/77	4.39	1.38	32.4	7.8	40.2	16.6	38.0

[*] Manure applications were on 11/9/76 and 3/8/77.

[†] A rainfall of 1.55 cm occurred on 3/5/77.

[‡] Mean concentration is total mass transport divided by total runoff volume.

In summary, variations in concentrations occurred within runoff events in response to changes in rain intensity and runoff rate and perhaps the amount of nutrients or organic materials available for runoff. However, the variations for a particular event and plot were usually small. The mass transport for a particular event is thus probably dominated by the runoff amount rather than by variations in concentration. If the runoff was sampled for concentrations during the peaks of the runoff rates, the mean of these concentrations and total runoff amount would likely allow a good estimate of mass transport without analyzing a large number of samples for concentration.

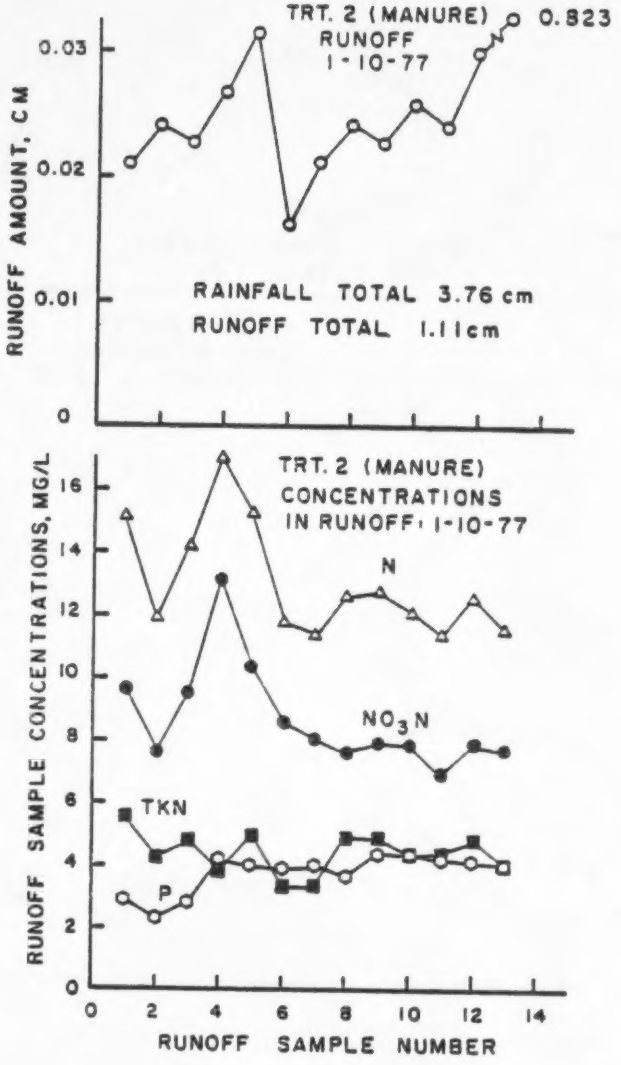

Figure 19. Variation of concentrations and associated sample volumes during the runoff event of 1-10-77.

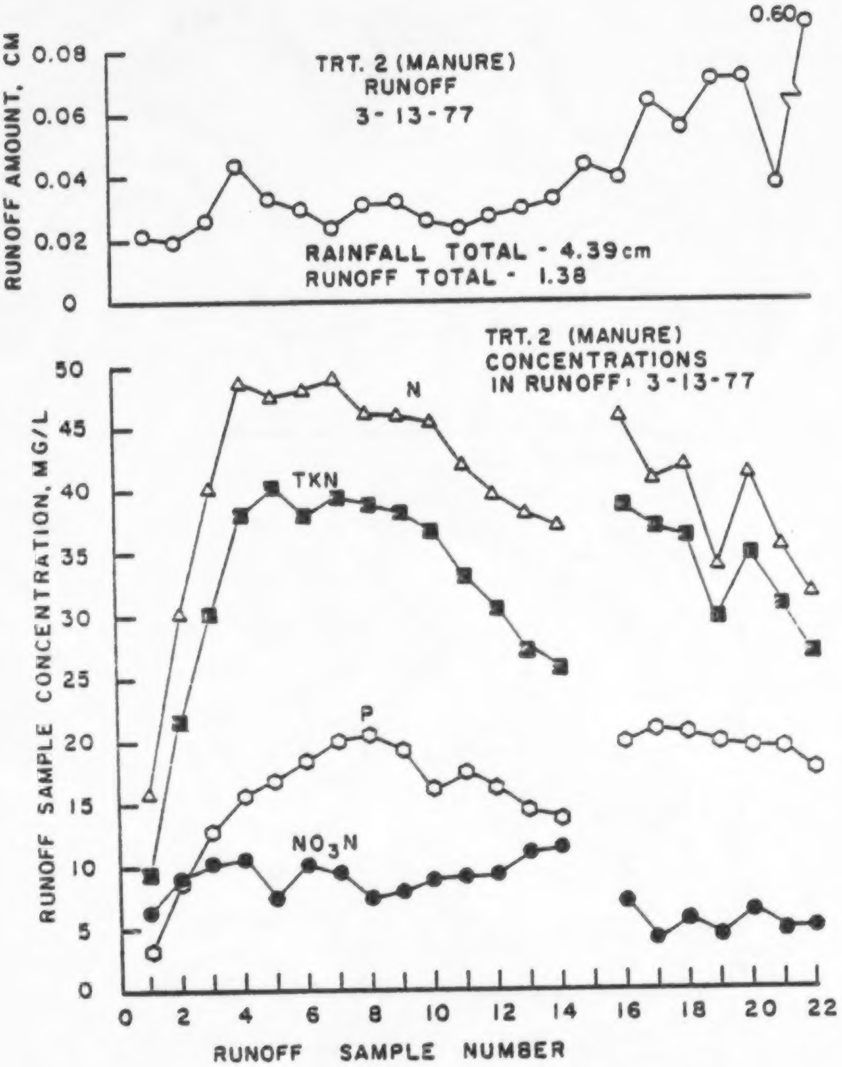

Figure 20. Variation of concentrations and associated sample volumes during the runoff event of 3-13-77.

MASS TRANSPORT IN RAINFALL RUNOFF

The rainfall runoff from the fescue plots was lower than expected, and thus, even though some nutrient concentrations in runoff were high, the mass transport of nutrients and organics was generally less than 1 to 2 percent of the amount of nutrient applied. The mass transport over the entire period is discussed, and transport during the last year (3/78 - 2/79) is discussed in more detail.

Mass Transport Over the Entire Period

Mass transport of selected runoff constituents for each runoff year and the sums for the entire period are shown in Table 34. The high-rate irrigation plot had the highest transport of every constituent each year except for 1976 and 1977 when the manure plot had higher transport of P and TOC and also Cl^- in 1976. The high-rate irrigation treatment (treatment 7) and the manure treatment (treatment 2) had the highest overall transport of constituents. Total transport for the treatments can be seen in Figure 21 for TKN, NO_3-N and N. The fertilizer treatments and the low-rate irrigation treatments had similar amounts of mass transport of N, TKN, and NO_3-N. The manure and high-rate irrigation treatments clearly had more total N transport in runoff, but the amounts in runoff were only 1.3% of the N applied to these treatments. Thus, runoff transport accounts for only a small amount of the nutrients applied. The environmental impact of these amounts of nutrient transport would depend on the particular site and the characteristics of the stream or reservior receiving the runoff.

The variation in annual mass transport for a particular treatment was mainly due to variation in runoff amounts. For example, the mass transport of N and P from treatment 7 varied with the same trend as runoff volume, but the volume-weighted concentration normally had the opposite trend (Figure 22), which meant that when runoff volume increased, concentration normally decreased. However, with relatively small amounts of runoff for annual periods, the effect of one highly-polluted runoff event could have a large effect on these trends. Thus, the manure and fertilizer treatments which had high potential for nutrient runoff just after applications of manure or fertilizer were more likely to vary from these trends.

Mass Transport for the Period March 1978 - February 1979

The mass transport of nutrients, including NH_3-N and OP, for the last period (March 1978 - February 1979) is shown in Table 35. This fourth period had the largest amounts of runoff and mass transport for almost all plots and nutrients. The highest transport of N was for the high-rate irrigation plot (treatment 7) and was 23.7 kg/ha which was about 1.8% of applied amount. The highest transport for a fertilizer treatment was from treatment 3 and was 8.8 kg/ha which was about 4.4% of applied amount. Of this 8.8 kg/ha, 5.1 kg/ha was in April when a large runoff event (4.1 cm) occurred six days after a fertilizer application. Thus, the possible effect of one event on the annual amount of runoff and mass is again demonstrated for treatments which received periodic, relatively large applications of nutrients in a form which was available for runoff transport.

TABLE 34. MASS TRANSPORT IN RAINFALL RUNOFF

Tmt. type	Tmt. no.	Mass in rainfall runoff, kg/ha*				
		Runoff year				Entire period
		1975	1976	1977	1978	
		TKN				
Fert.	3	3.4	0.2	1.1	4.7	9.5
Fert.	5	3.5	0.4	1.1	1.9	6.9
Low irg.	4	1.2	0.2	0.7	3.5	5.7
Low irg.	6	1.7	0.3	1.7	4.2	7.9
High irg.	7	6.6	2.3	3.2	10.3	22.5
Manure	2	3.3	1.0	5.1	9.6	19.0
		NO_3-N				
Fert.	3	1.7	0.1	0.6	4.1	6.5
Fert.	5	0.7	0.3	0.8	0.8	2.7
Low irg.	4	1.0	0.2	1.6	2.0	4.7
Low irg.	6	3.5	0.1	1.3	2.9	7.9
High irg.	7	19.2	1.0	6.6	13.3	40.1
Manure	2	1.2	2.3	2.1	8.5	14.0
		N				
Fert.	3	5.1	0.3	1.7	8.8	16.0
Fert.	5	4.2	0.7	1.9	2.7	9.6
Low irg.	4	2.2	0.4	2.3	5.5	10.4
Low irg.	6	5.2	0.4	3.0	7.1	15.8
High irg.	7	25.8	3.3	9.8	23.6	62.6
Manure	2	4.5	3.3	7.2	18.1	33.0
		P				
Fert.	3	0.26	0.05	0.38	0.99	1.69
Fert.	5	0.53	0.08	0.24	0.40	1.25
Low irg.	4	0.22	0.05	0.65	1.15	2.07
Low irg.	6	0.40	0.07	0.58	1.96	3.01
High irg.	7	5.53	0.61	1.83	11.16	19.13
Manure	2	0.32	0.97	2.69	8.34	12.31
		TOC				
Fert.	3	14.3	1.4	7.3	32.2	55.2
Fert.	5	7.9	1.5	2.5	11.6	23.6
Low irg.	4	6.1	1.0	3.6	19.6	30.3
Low irg.	6	11.8	2.0	8.8	28.7	51.3
High irg.	7	34.8	4.5	13.1	55.6	108.0
Manure	2	7.3	7.0	18.2	36.5	69.1

(continued)

TABLE 34 (continued)

Tmt. type	Tmt. no.	Mass in rainfall runoff, kg/ha*				
		Runoff year^≠				Entire period
		1975	1976	1977	1978	
		Cl^-				
Fert.	3	2.0	0.4	1.2	6.4	10.0
Fert.	5	2.6	1.0	1.3	1.9	6.8
Low irg.	4	2.2	0.6	3.1	7.1	13.1
Low irg.	6	3.3	1.0	4.0	9.8	18.0
High irg.	7	18.2	1.2	11.5	17.9	48.8
Manure	2	1.6	2.3	5.5	8.6	17.4

*Missing data occurred for both rainfall volume and concentration. Most concentration missing data was for Cl^- and P in July 1975. For details of runoff-volume missing data, see Table D-1.

≠Runoff year is for March through February except for first year when data began in July 1975.

The monthly variation of mass transport for the various plots is shown for TKN in Table D-3. This table demonstrates the monthly variability and how the annual sum can be significantly affected by one month which has one or more large rainfall-runoff events.

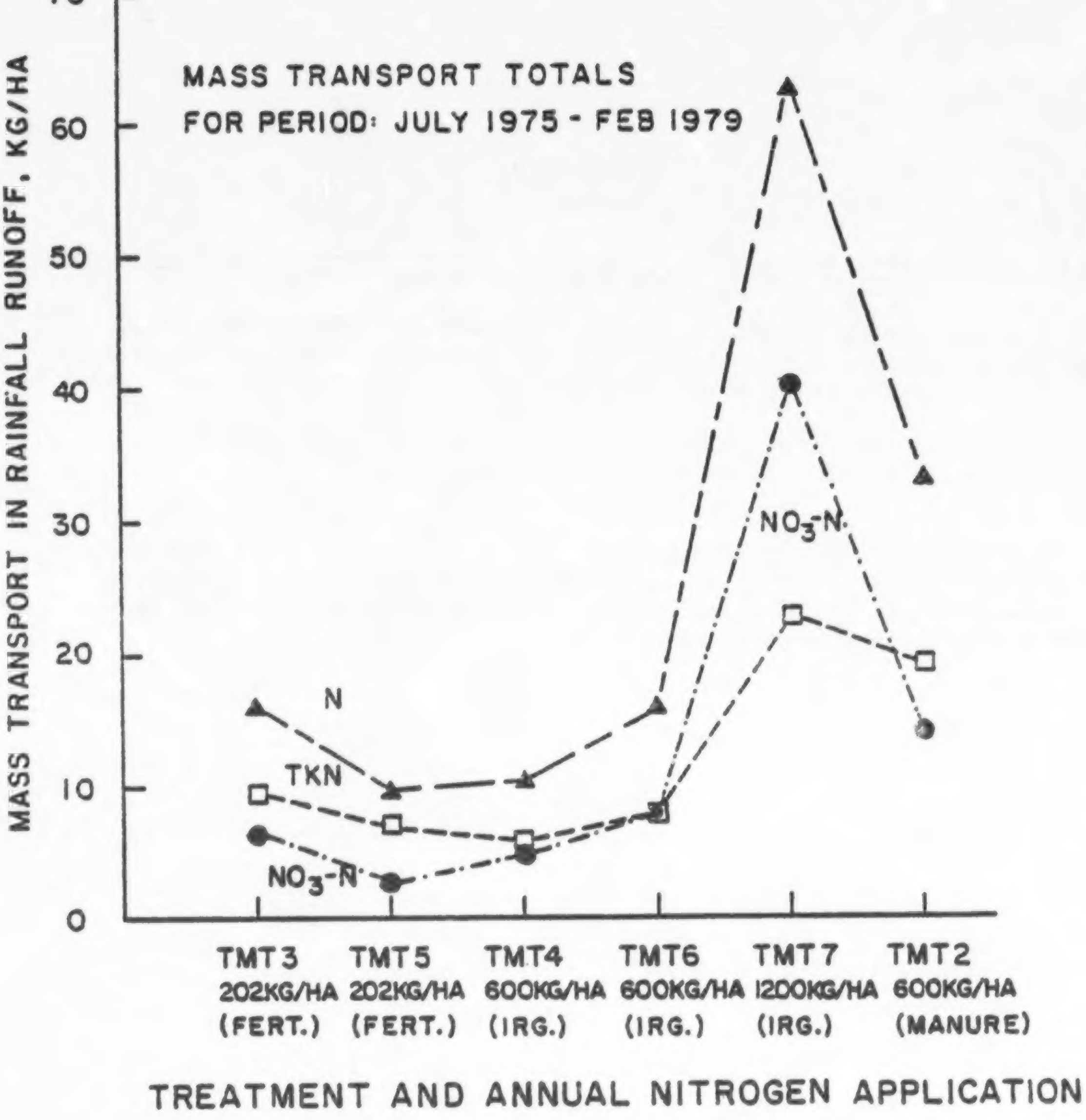

Figure 21. Mass transport of N, TKN, and NO_3-N in rainfall runoff for entire period.

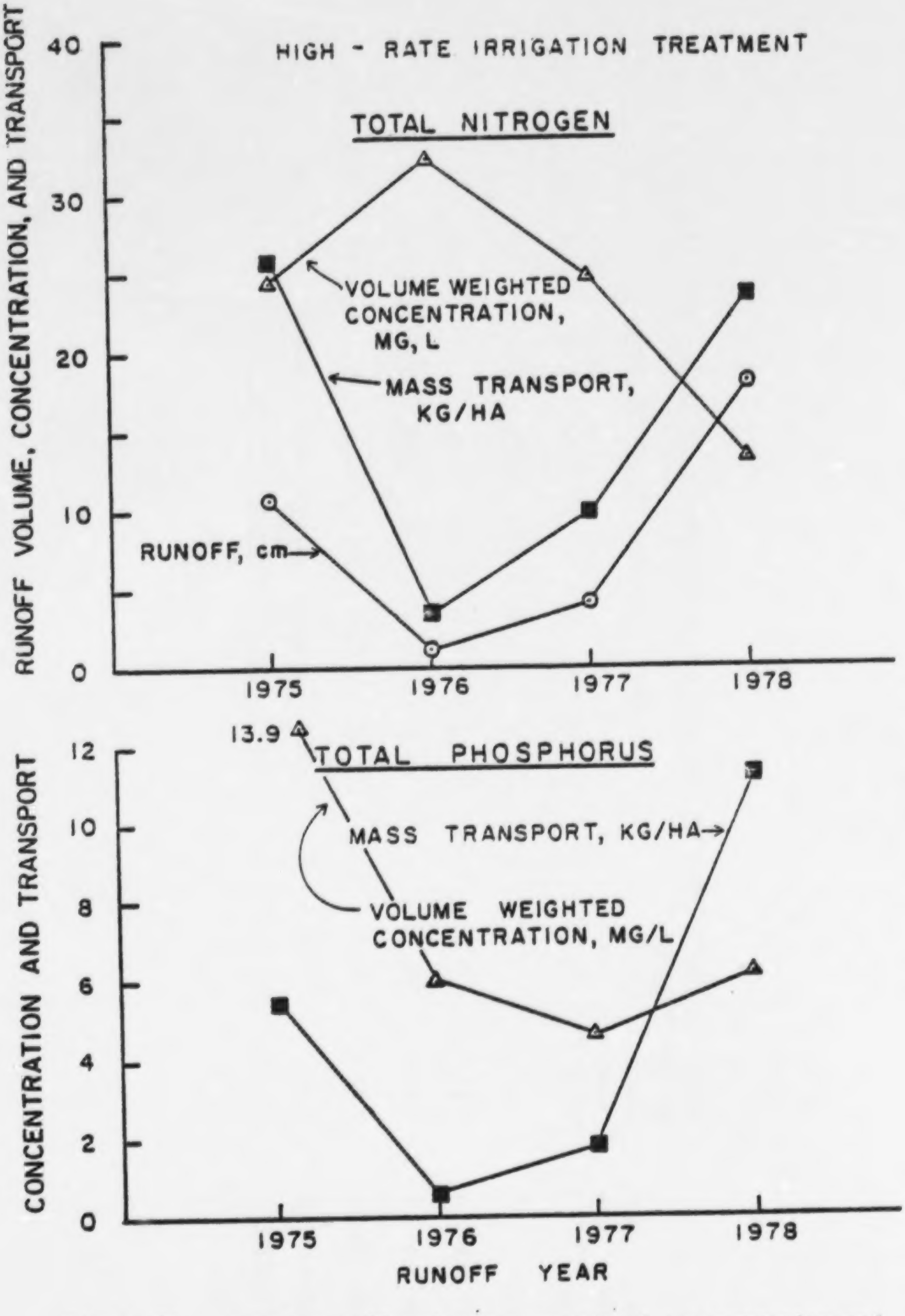

Figure 22. Annual runoff and volume-weighted concentration and mass transport of N and P.

TABLE 35. MASS TRANSPORT IN RAINFALL RUNOFF FOR MARCH 1978 - FEB. 1979

Tmt. type	Tmt. no.	No. of runoff events	Runoff volume, cm	Mass transport in runoff, kg/ha							
				TKN	NH_3-N	NO_3-N	N	P	OP	TOC	Cl^-
Fert.	3	45	15.5	4.7	0.9	4.1	8.8	1.0	0.7	32	6.4
Fert.	5	28	6.2	1.9	0.3	0.8	2.7	0.4	0.2	12	1.9
Low irg.	4	19	9.0	3.5	0.3	2.0	5.5	1.1	0.9	20	7.1
Low irg.	6	23	11.2	4.2	0.6	2.9	7.1	2.0	1.5	29	9.7
High irg.	7	26	18.0	10.3	1.2	13.3	23.7	11.1	10.2	56	17.8
Manure	2	30	13.8	9.6	1.8	8.5	18.1	8.3	6.3	36	8.6

REFERENCES

APHA. 1971. Standard Methods for the Examination of Water and Wastewater. Thirteenth Edition. American Public Health Association. Washington, D.C. 847 pp.

Burns, J. C. and W. A. Cope. 1974. Nutritive value of crownvetch forage as influenced by structural constituents and phenolic and tannin compounds. Agron. J. 66:195-200.

Dobson, S. H., E. L. Kimbrough, J. V. Baird, W. W. Woodhouse and D. S. Chamblee. 1977. Tall fescue. AG-52. The North Carolina Agricultural Extension Service. N.C. State University, Raleigh, N.C.

Hojjati, S. M., T. H. Taylor and W. C. Templeton, Jr. 1972. Nitrate accumulation in rye, tall fescue and bermudagrass as affected by nitrogen fertilization. Agron. J. 64:624-627.

Hill, R. L. 1980. The effect of sodium and calcium solutions on the hydraulic conductivity of two North Carolina subsoils. M.S. Thesis, North Carolina State University, Raleigh, N.C.

Humenik, F. J. and M. R. Overcash. 1976. Design criteria for swine waste treatment systems. EPA-600/2-76-223. Robert S. Kerr Environmental Research Laboratory, U.S. E.P.A., Ada, Oklahoma.

Jackson, M. L. 1965. Soil Chemical Analysis. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 498 pp.

Murphy, L. S. and G. E. Smith. 1967. Nitrate accumulations in forage crops. Agron. J. 59:171-174.

NCSU. 1971. Weather and Climate. Bulletin 396, Agricultural Experiment Station, North Carolina State University, Raleigh, N.C.

Overcash, M. R. and F. J. Humenik. 1976. State-of-the-art: Swine waste production and pretreatment processes. EPA-600/2-76-290. Robert S. Kerr Environmental Research Laboratory, U.S. E.P.A., Ada, Oklahoma.

Overcash, M. R., J. W. Gilliam, F. J. Humenik and P. W. Westerman. 1978. Lagoon pretreatment: heavy metal and cation removals. J. Water Pollution Control Federation 50(8):2029-2036.

Technicon. 1973a. Industrial Method for NO_3^--N Extract Analysis #100-70 W. Technicon Industrial Systems. Tarrytown, N.Y.

Technicon. 1973b. Industrial Method for Cl^- Extract Analysis #99-70 W. Technicon Industrial Systems. Tarrytown, N.Y.

Technicon. 1974a. Industrial Method for Total and Orthophosphate Extract Analysis #327-74 W. Technicon Industrial Systems. Tarrytown, N.Y.

Technicon. 1974b. Industrial Method for NH_3-N and TKN Extract Analysis #325-74 W. Technicon Industrial Systems. Tarrytown, N.Y.

APPENDIX A

LAGOON AND IRRIGATION DATA
ON MONTHLY BASIS FOR 1976-1978

TABLE A-1 LAGOON MONTHLY CONCENTRATIONS*

Year	Month	N	P	K	Ca	Mg	Na	Cl^-
		Concentration of element, mg/ℓ						
1976	May	630	100	1,180	85	27	420	390
	June	500	80	1,160	85	35	430	370
	July	510	110	810	125	46	500	400
	August	490	66	1,190	155	53	550	550
	Sept.	500	70	1,050	125	36	490	490
	Oct.	520	61	1,070	135	35	560	480
	Nov.	530	54	940	105	20	470	460
	Mean	**530**	**77**	**1,060**	**115**	**36**	**490**	**450**
1977	March	590	119	560	66	19	330	340
	April[§]	440	78	540	69	20	290	320
	May[§]	520	71	540	69	20	290	390
	June	440	70	570	66	14	330	360
	July	530	81	800	60	14	320	500
	August	520	90	910	58	14	320	590
	Sept.	440	90	670	53	20	300	450
	Oct.	420	136	610	67	22	290	430
	Nov.	350	80	490	76	25	300	400
	Mean	470	91	630	65	19	310	420
1978	March	470	105	290	86	23	170	300
	April	470	76	430	82	18	220	310
	May	390	64	390	60	11	180	280
	June	310	64	440	59	16	200	310
	July[+]	290	84	520	147	61	200	320
	August	260	103	360	59	34	230	300
	Sept.	290	89	350	58	30	210	310
	Oct.	250	68	300	63	35	270	290
	Nov.	250	76	270	56	23	240	360
	Mean	330	81	370	74	28	210	310

(Continued)

TABLE A-1 (continued)

Year	Month	Concentration of element, mg/ℓ					
		Cu	Zn	COD	TOC	OP	NH_3-N
1976	May	0.07	0.7	2,200	600	-	-
	June	0.10	0.8	2,400	600	-	-
	July	0.15	0.7	2,000	1,000	51	430
	August	0.26	0.8	2,800	1,200	61	410
	Sept.	0.15	0.5	2,100	850	51	410
	Oct.	0.25	0.8	2,000	800	52	410
	Nov.	0.19	0.6	2,100	1,350	49	450
	Mean	0.17	0.7	2,200	900	53	420
1977	March§	0.09	0.6	2,100	400	98	470
	April§	0.09	0.6	1,900	250	74	400
	May	0.09	0.6	1,800	650	87	490
	June	0.08	0.6	900	350	61	410
	July	0.10	0.5	1,700	550	74	460
	August	0.06	0.4	2,300	650	74	360
	Sept.	0.04	0.4	1,700	450	76	300
	Oct.	0.06	0.7	2,400	400	123	330
	Nov.	0.07	0.5	1,400	300	73	300
	Mean	0.08	0.5	1,800	450	82	390
1978	March	0.13	1.4	2,100	300	-	380
	April	0.07	0.4	1,400	250	69	450
	May	0.08	0.8	800	300	58	350
	June+	0.06	0.3	1,200	350	78	270
	July	0.38	3.9	1,700	550	67	220
	August	0.08	0.4	1,800	550	77	180
	Sept.	0.09	0.3	1,600	700	58	160
	Oct.	0.09	0.5	1,700	600	58	170
	Nov.	0.06	0.4	1,700	750	63	170
	Mean	0.12	0.9	1,600	500	66	260

* Monthly means calculated using values from weekly samples.

§ The combined monthly mean for April and May of 1977 are from 4 values for April and 1 for May for all except N, P and Cl.

+ July, 1978 lagoon samples included more solids which was likely due to pumping from lagoon and stirring up sludge from bottom.

TABLE A-2 IRRIGATION COLLECTION CUP LIQUID CONCENTRATIONS*

Year	Month	Concentration of element, mg/ℓ						
		N	P	K	Ca	Mg	Na	Cl^-
1976	May	490	66	-	155	66	-	390
	June	330	44	-	100	56	-	330
	July	340	53	-	70	8	-	450
	August	280	59	-	110	32	-	560
	Sept.	440	53	-	110	46	-	-
	Oct.	490	52	-	100	26	-	510
	Nov.	490	51	-	110	11	-	480
	Mean	410	54		108	35		518
1977	March	500	110	-	150	69	490	320
	April	420	87	-	85	10	330	370
	May	470	100	-	105	42	360	400
	June	350	62	550	95	18	310	430
	July	450	85	1080	100	31	430	530
	August	400	87	810	50	15	350	650
	Sept.	370	70	710	55	24	320	460
	Oct.	330	62	700	80	16	400	420
	Nov.	260	52	600	-	-	-	350
	Mean	390	79	740	80	28	373	437
1978	March	410	71	360	70	19	200	300
	April	430	77	480	70	13	230	300
	May	340	55	390	55	12	190	280
	June	260	48	480	50	15	200	330
	July	200	62	540	60	25	210	310
	August	230	84	280	60	32	300	300
	Sept.	250	78	290	60	32	280	310
	Oct.	220	87	300	60	30	250	280
	Nov.	200	49	260	65	31	310	330
	Mean	280	68	380	61	23	241	304

(Continued)

TABLE A-2 (continued)

		Concentration of element, mg/ℓ					
Year	Month	Cu	Zn	COD	TOC	OP	NH_3-N
1976	May	0.28	1.0	2,100	500	-	-
	June	0.27	1.9	1,600	550	-	-
	July	0.20	0.4	1,600	1,000	-	-
	August	0.50	2.8	1,900	850	-	-
	Sept.	0.20	1.0	2,200	950	-	-
	Oct.	0.18	0.8	1,700	1,000	-	-
	Nov.	0.30	1.2	2,200	1,600	-	-
	Mean	0.28	1.3	1,900	900	-	-
1977	March	0.60	1.3	2,300	500	102	420
	April	0.85	1.3	1,900	250	77	380
	May	0.33	0.8	1,300	400	107	450
	June	0.26	1.0	1,000	400	58	320
	July	0.18	1.2	1,700	600	75	350
	August	0.07	0.4	2,000	600	82	250
	Sept.	0.07	0.5	1,600	450	58	250
	Oct.	0.12	0.7	1,600	400	54	260
	Nov.	-	-	1,300	400	47	240
	Mean	0.28	0.8	1,600	450	73	320
1978	March	0.11	0.6	1,700	250	-	360
	April	0.13	0.9	1,200	250	65	390
	May	0.08	0.6	900	250	53	300
	June	0.09	0.7	1,200	350	53	220
	July	0.07	0.4	1,200	400	53	160
	August	0.06	0.3	1,800	500	62	150
	Sept.	0.07	0.3	1,300	600	35	120
	Oct.	0.07	0.4	1,400	600	49	130
	Nov.	0.09	0.5	1,700	600	47	160
	Mean	0.09	0.5	1,400	400	52	220

* Monthly mean calculated using one mean value for each irrigation event that had data and no rainfall mixed in. Each event mean was calculated from 4 plots, 4 cups per plot.

TABLE A-3. RATIO OF IRRIGATION CUP LIQUID CONCENTRATION TO LAGOON LIQUID CONCENTRATION, MONTHLY MEANS*

		Ratio of concentrations in cup to that in lagoon						
Year	Month	N	P	K	Ca	Mg	Na	Cl⁻
1976	May	.78	.66	-	1.82	2.44	-	1.00
	June	.66	.55	-	1.18	1.60	-	0.89
	July	.67	.48	-	0.56	0.17	-	1.13
	August	.57	.89	-	0.71	0.60	-	1.02
	Sept.	.88	.76	-	0.88	1.28	-	-
	Oct.	.94	.85	-	0.74	0.74	-	1.06
	Nov.	.92	.94	-	1.05	0.55	-	1.04
	Mean	.77	.73	-	0.99	1.05	-	1.02
	Std. Dev.	.14	.18	-	0.73	1.34	-	0.13
1977	March	.85	0.92	-	2.27	3.63	1.48	0.94
	April	.95	1.12	-	1.23	0.50	1.14	1.16
	May	.90	1.41	-	1.52	2.1	1.24	1.03
	June	.80	0.89	0.96	1.44	1.29	0.94	1.19
	July	.85	1.05	1.35	1.67	2.21	1.34	1.06
	August	.77	0.97	0.89	0.86	0.75	1.17	1.10
	Sept.	.84	0.78	1.06	1.04	1.09	1.10	1.02
	Oct.	.79	0.46	1.15	1.19	0.72	1.33	1.02
	Nov.	.74	0.65	1.22	-	-	-	0.88
	Mean	.83	0.92	1.11	1.41	1.54	1.22	1.04
	Std. Dev.	.06	0.27	0.27	0.8	1.97	0.31	0.20
1978	March	.87	0.68	1.24	0.81	0.82	1.18	1.00
	April	.91	1.01	1.12	0.85	0.72	1.05	0.97
	May	.87	0.86	1.00	0.92	1.09	1.06	1.00
	June	.84	0.75	1.09	0.85	0.94	1.00	1.06
	July	.69	0.74	1.04	0.41	0.41	1.05	0.97
	August	.88	0.82	0.78	1.02	0.94	1.30	1.00
	Sept.	.86	0.88	0.83	1.03	1.07	1.33	1.00
	Oct.	.88	1.28	1.00	0.95	0.86	0.93	0.97
	Nov.	.80	0.64	0.97	1.16	1.35	1.29	0.92
	Mean	.84	0.85	1.01	0.89	0.91	1.13	0.99
	Std. Dev.	.06	0.20	0.30	0.42	0.52	0.29	0.08
	Annual Mean	.81	0.83	1.06	1.10±	1.17	1.18	1.02
	Std. Dev.	.04	0.10	0.07	0.27	0.33	0.06	0.03

(Continued)

TABLE A-3 (continued)

Year	Month	Ratio of concentrations in cup to that in lagoon					
		Cu	Zn	COD	TOC	OP	NH_3-N
1976	May	0.25	1.4	0.95	0.83	-	-
	June	0.37	2.4	0.67	0.92	-	-
	July	0.75	0.6	0.80	1.00	-	-
	August	0.52	3.5	0.68	0.71	-	-
	Sept.	0.75	2.0	1.05	1.12	-	-
	Oct.	1.39	1.0	0.85	1.25	-	-
	Nov.	0.63	2.0	1.05	1.19	-	-
	Mean	0.65	1.8	0.86	1.00	-	-
	Std. Dev.	0.64	1.0	0.16	0.20	-	-
1977	March	0.15	2.2	1.10	1.25	1.04	.89
	April	0.11	2.2	1.00	1.00	1.04	.95
	May	0.27	1.3	0.72	0.62	1.23	.92
	June	0.31	1.7	1.11	1.14	0.95	.78
	July	0.56	2.4	1.00	1.09	1.01	.76
	August	0.86	1.0	0.87	0.92	1.11	.69
	Sept.	0.57	1.2	0.94	1.00	0.76	.83
	Oct.	0.86	1.0	0.67	1.00	0.44	.79
	Nov.	0.58	-	0.93	1.33	0.64	.80
	Mean	0.47	1.6	0.93	1.04	0.91	.82
	Std. Dev.	0.56	0.6	0.15	0.20	0.25	.08
1978	March	1.18	0.4	0.81	0.83	-	.95
	April	0.54	2.2	0.86	1.00	0.94	.87
	May	1.00	0.8	1.12	0.83	0.91	.86
	June	0.67	2.3	1.00	1.00	0.68	.81
	July	5.43	0.1	0.71	0.73	0.79	.73
	August	1.33	0.8	1.00	0.91	0.80	.83
	Sept.	1.29	1.0	0.81	0.86	0.60	.75
	Oct.	1.29	0.8	0.82	1.00	0.84	.76
	Nov.	0.67	1.2	1.00	0.80	0.75	.94
	Mean	1.49	1.1	0.90	0.88	0.79	.83
	Std. Dev.	3.02	0.7	0.13	0.10	0.11	.08
	Annual Mean	0.87	1.5	0.90	0.97	0.85	.82
	Std. Dev.	0.54	0.4	0.04	0.08	0.08	.01

* Ratios calculated from concentration values in Tables A-1 and A-2.

TABLE A-4. MONTHLY IRRIGATION AMOUNTS

Year	Month	n[*]	Irrigation amount, cm			
			Tmt. 1	Tmt. 4	Tmt. 6	Tmt. 7
1975[§]	April	3	1.56	1.56	1.56	2.52
	May	5	2.60	2.60	2.60	4.20
	June	4	2.08	2.08	2.08	3.36
	July	4	2.08	2.08	2.08	3.36
	Aug.	5	2.60	2.60	2.60	4.20
	Sept.	4	2.36	2.36	2.36	5.08
	Oct.	6	4.96	4.96	4.96	19.32
	Nov.	2	1.82	1.82	1.82	7.96
	Total	33	20.06	20.06	20.06	50.00
1976	May	4	2.56	2.92	2.61	4.53
	June	4	1.23	2.15	1.45	5.54
	July	5	1.38	1.62	1.91	2.14
	Aug.	4	0.63	0.79	1.25	1.70
	Sept.	4	1.43	1.83	1.60	2.44
	Oct.	5	1.74	2.53	2.59	3.86
	Nov.	2	1.23	1.39	1.51	2.44
	Total	28	10.20	13.23	12.92	22.65
1977	March	5	1.81	1.75	1.82	3.10
	April	4	1.44	1.20	1.50	2.23
	May	4	0.98	1.35	1.70	2.70
	June	4	0.49	0.88	1.67	3.25
	July	4	1.73	2.42	3.13	5.07
	Aug.	4	2.12	2.26	2.32	5.23
	Sept.	4	2.18	2.38	2.23	4.87
	Oct.	4	2.33	2.60	2.00	3.07
	Nov.	2	0.64	0.97	0.87	2.36
	Total	35	13.72	15.81	17.24	31.88

(continued)

TABLE A-4 (continued)

Year	Month	n*	Irrigation amount, cm Tmt. 1	Tmt. 4	Tmt. 6	Tmt. 7
1978	March	3	2.62	2.27	1.64	3.80
	April	4	2.52	2.81	1.87	4.31
	May	4	2.58	2.75	2.29	4.96
	June	5	3.22	2.87	2.55	6.06
	July	4	2.24	1.99	1.60	4.47
	Aug.	4	3.31	3.58	3.03	7.08
	Sept.	5	2.81	3.60	1.77	6.53
	Oct.	5	3.63	3.74	5.86	6.78
	Nov.	2	1.85	1.77	2.54	2.47
	Total	36	24.78	25.38	23.15	46.46

* n is number of irrigation events.

§ In 1975, usually only 2 plots chosen at random had collection cups. Thus, the amounts on treatments 1, 4, and 6 were estimated from mean volumes from 1 or 2 of these plots per irrigation event normally and assuming equal distribution on all 3 plots. The amount on treatment 7 was estimated from only the events which had collection cups on this plot and multiplying average volume by number of irrigations within a period. For 1976, 1977 and 1978 each plot had collection cups (4 per plot).

APPENDIX B

CROP RESPONSE RESULTS
FOR EACH YEAR

TABLE B-1. YEARLY DRY MATTER, N AND NO_3-N YIELDS

Item	Land slope							
	3-5%				8-10%			
	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
	kg/ha							
Dry matter yield:								
1974	3,995	1,606	1,874	3,700	3,167	4,222	5,105	3,381
1975	10,095	4,903	5,802	9,750	9,090	10,546	13,792	9,140
1976	13,411	9,732	9,690	12,629	11,447	14,351	16,456	12,530
1977	9,171	6,650	4,932	10,068	6,531	9,294	7,958	7,800
1978	10,842	9,044	7,328	11,504	8,102	12,307	11,772	10,157
Mean	9,503	6,387	5,925	9,531	7,667	10,184	11,017	8,602
4-yr* Mean	10,880	7,383	6,938	10,987	8,792	11,674	12,495	9,907
Total nitrogen:								
1974	121	51	54	123	88	124	167	104
1975	301	164	181	318	262	305	423	279
1976	452	354	373	463	411	490	577	446
1977	335	279	179	382	237	357	314	298
1978	379	317	226	394	227	415	416	339
Mean	317	233	203	336	245	338	380	293
4-yr Mean	366	278	240	389	285	391	432	341
Nitrate nitrogen:								
1974	1.81	0.17	0.06	0.96	0.58	1.41	8.49	1.93
1975	13.09	2.32	1.33	12.76	4.57	13.10	28.08	10.76
1976	16.38	8.33	13.35	23.04	13.63	19.58	42.73	19.58
1977	17.22	22.07	2.50	20.82	6.94	23.20	22.42	16.45
1978	16.23	24.25	1.35	14.89	2.24	14.15	40.09	16.17
Mean	12.95	11.43	3.72	14.50	5.39	14.29	28.36	12.98
4-yr Mean	15.73	14.24	4.63	17.87	6.85	17.50	33.33	15.73

* 4 yrs = 1975, 1976, 1977 and 1978 (1974 started in August).

TABLE B-2. YEARLY IVDMD, N AND NO_3-N CONCENTRATIONS IN FORAGE

		Land slope							
		3-5%				8-10%			
Item		Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)		(1)	(2)	(30	(4)	(5)	(6)	(7)	
		%							
Dry matter disappearance:									
	1974	61.3	62.0	59.5	66.4	59.4	59.9	61.1	61.4
	1975	60.0	64.5	61.6	64.0	61.6	60.8	59.3	61.7
	1976	68.5	68.9	67.7	71.7	67.5	69.3	70.7	69.2
	1977	66.3	70.7	69.6	69.5	70.4	67.8	70.5	69.3
	1978	70.0	70.0	68.3	71.4	70.4	70.2	67.5	69.7
	Mean	65.2	67.2	65.3	68.6	65.9	65.6	65.8	66.3
4-yr*	Mean	66.2	68.5	66.8	69.2	67.5	67.0	67.0	67.5
Total nitrogen:									
	1974	3.03	3.19	2.88	3.33	2.81	2.95	3.26	3.07
	1975	2.99	3.33	3.13	3.27	2.89	2.89	3.08	3.08
	1976	3.36	3.64	3.85	3.66	3.59	3.41	3.51	3.57
	1977	3.65	4.20	3.63	3.80	3.64	3.85	3.94	3.82
	1978	3.49	3.30	3.09	3.43	2.31	3.31	3.53	3.31
	Mean	3.31	3.51	3.31	3.50	3.15	3.28	3.47	3.37
4-yr	Mean	3.37	3.67	3.43	3.54	3.23	3.37	3.52	3.45
Nitrate nitrogen:		ppm							
	1974	454	104	32	260	185	334	1,665	433
	1975	1,297	473	230	1,309	503	1,242	2,037	1,013
	1976	1,222	856	1,377	1,825	1,190	1,364	2,596	1,490
	1977	1,879	3,321	507	2,068	1,062	2,496	2,817	2,021
	1978	1,497	2,682	185	1,294	277	1,131	3,406	1,496
	Mean	1,270	1,487	466	1,351	643	1,313	2,504	1,291
4-yr	Mean	1,474	1,833	575	1,624	758	1,558	2,714	1,505

*4 yrs = 1975, 1976, 1977 and 1978 (1974 started in August).

TABLE B-3. YEARLY P, K, CA, MG, AND CL^- CONCENTRATIONS IN FORAGE

		Land slope							
		3-5%				8-10%			
Item		Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (762 kg N/ha)	Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)		(1)	(2)	(3)	(4)	(5)	(6)	(7)	
		%							
Phosphorus:									
	1974	0.42[+]	0.45	0.40	0.46	0.41	0.43	0.42	0.43
	1975	0.35	0.37	0.29	0.38	0.31	0.38	0.37	0.35
	1976	0.36	0.39	0.32	0.38	0.36	0.41	0.42	0.38
	1977	0.39	0.48	0.32	0.39	0.35	0.40	0.43	0.39
	1978	0.41	0.36	0.35	0.41	0.40	0.43	0.47	0.41
	Mean	0.39	0.41	0.34	0.40	0.37	0.41	0.42	0.39
4-yr*	Mean	0.38	0.40	0.32	0.39	0.36	0.41	0.42	0.38
Potassium:									
	1974	3.12	2.53	2.24	3.31	2.61	3.04	3.77	2.95
	1975	3.31	2.80	2.71	3.32	2.50	3.27	3.43	3.05
	1976	3.34	3.10	3.40	3.63	2.87	3.83	4.16	3.47
	1977	3.87	3.70	2.79	3.96	2.92	3.94	4.31	3.64
	1978	3.92	3.72	2.63	3.98	2.59	4.27	4.81	3.70
	Mean	3.51	3.17	2.75	3.64	2.70	3.67	4.09	3.36
4-yr	Mean	3.61	3.33	2.88	3.72	2.72	3.82	4.18	3.47
Calcium:									
	1974	0.38	0.62	0.56	0.39	0.40	0.37	0.37	0.44
	1975	0.43	0.49	0.49	0.40	0.43	0.36	0.36	0.42
	1976	0.31	0.34	0.43	0.31	0.39	0.30	0.33	0.34
	1977	0.33	0.46	0.43	0.33	0.37	0.32	0.33	0.37
	1978	0.29	0.42	0.37	0.30	0.38	0.30	0.41	0.35
	Mean	0.35	0.46	0.45	0.35	0.39	0.33	0.36	0.38
4-yr	Mean	0.34	0.43	0.43	0.34	0.39	0.32	0.36	0.37
Magnesium:									
	1974	0.31	0.34	0.36	0.31	0.32	0.31	0.31	0.32
	1975	0.32	0.30	0.34	0.31	0.33	0.30	0.30	0.31
	1976	0.30	0.29	0.36	0.31	0.35	0.31	0.32	0.32
	1977	0.29	0.33	0.36	0.31	0.35	0.31	0.29	0.32
	1978	0.33	0.41	0.33	0.34	0.35	0.32	0.39	0.35
	Mean	0.31	0.33	0.35	0.31	0.34	0.31	0.32	0.32
4-yr	Mean	0.31	0.33	0.35	0.32	0.35	0.31	0.33	0.33

(Continued)

TABLE 8-3 (continued)

Item	Land slope							
	3-5%				8-10%			
	Lagoon effluent (672 kg N/ha	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (762 kg N/ha)	Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
	%							
Chloride:								
1974	1.61	0.96	0.91	1.40	1.03	1.32	1.72	1.28
1975	1.20	1.03	0.89	1.38	0.74	1.31	1.08	1.09
1976	1.55	1.28	1.19	1.53	1.06	1.48	1.31	1.34
1977	1.66	1.04	1.16	1.73	1.01	1.53	1.57	1.39
1978	1.46	1.21	1.30	1.54	1.07	1.45	1.47	1.36
Mean	1.49	1.10	1.09	1.51	1.23	1.42	1.43	1.29
4-yr Mean	1.47	1.14	1.14	1.55	0.97	1.44	1.36	1.30

* 4-yrs = 1975, 1976, 1977 and 1978 (1974 started in August).

[+] Values are averages weighted for individual dry matter yields at each harvest.

TABLE B-4. YEARLY MN, CU, ZN, FE AND NA CONCENTRATIONS IN FORAGE

	Land slope							
	3-5%				8-10%			
Item	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
	ppm							
Manganese:								
1974	43[†]	55	45	45	70	68	56	54
1975	44	49	31	55	81	62	50	53
1976	33	52	34	43	116	47	73	57
1977	42	95	36	41	111	56	75	65
1978	31	106	37	41	151	50	62	68
Mean	39	71	37	45	106	57	63	59
4-yr* Mean	38	76	35	45	115	54	65	61
Copper:								
1974	8	11	9	8	10	9	9	9
1975	9	9	8	8	8	7	6	8
1976	8	9	9	7	7	7	8	8
1977	10	13	9	8	8	7	7	9
1978	9	11	7	7	7	7	7	9
Mean	9	11	8	8	8	7	7	9
4-yr Mean	9	11	8	8	8	7	7	9
Zinc:								
1974	35	56	43	39	43	43	52	47
1975	38	49	40	38	41	41	41	41
1976	36	57	39	37	42	40	51	43
1977	42	98	49	43	47	44	52	53
1978	45	87	36	45	56	46	61	54
Mean	39	69	41	40	46	43	51	48
4-yr Mean	40	73	41	41	47	43	51	48
Iron:								
1974	1,163	1,360	1,413	755	1,816	1,168	1,812	1,355
1975	1,028	932	466	655	870	676	859	784
1976	866	638	575	420	678	417	744	620
1977	950	1,185	1,377	539	580	549	429	801
1978	337	860	309	288	396	360	300	407
Mean	869	995	828	531	858	634	829	793
4-yr Mean	795	904	682	476	631	501	583	653

(continued)

TABLE 3-4 (continued)

Item	Land slope							
	3-5%				8-10%			
	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Sodium:					ppm			
1974	686	624	100	705	117	643	1,111	569
1975	733	335	147	738	264	862	1,131	601
1976	1,070	482	410	1,143	523	1,183	1,716	933
1977	1,649	1,215	593	1,628	1,000	1,715	2,054	1,408
1978	1,219	768	561	1,141	734	1,315	1,841	1,083
Mean	1,072	685	362	1,071	527	1,144	1,571	919
4-yr Mean	1,168	700	428	1,163	630	1,269	1,686	1,006

* 4 yrs = 1975, 1976, 1977 and 1978 (1974 (1974 started in August)

+ Values are averages weighted for individual dry matter yields at each harvest.

TABLE B-5. YEARLY QUANTITIES OF P, K, CA, MG, AND CL$^-$ REMOVED IN THE FORAGE

	Land slope							
	3-5%				8-10%			
Item	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Phosphorus:	kg/ha							
1974	16.8	7.2	7.5	17.0	13.0	17.9	21.4	14.4
1975	35.7	18.1	17.1	36.7	28.5	40.2	50.6	32.4
1976	48.3	38.4	31.4	47.6	40.7	58.1	68.7	47.6
1977	36.1	31.7	15.8	39.8	23.0	36.7	34.2	31.0
1978	44.3	32.6	25.9	47.3	32.5	53.8	54.9	41.6
Mean	36.2	25.7	19.5	37.6	27.6	41.3	45.9	33.4
4-yr* Mean	41.1	30.2	22.5	42.8	31.1	47.2	52.1	38.1
Potassium:								
1974	124.6	40.7	42.0	122.5	82.7	128.3	192.5	104.8
1975	333.9	137.5	157.5	323.5	227.1	344.2	473.2	285.3
1976	447.6	301.8	329.2	458.8	327.9	549.1	684.1	442.6
1977	354.9	246.0	137.7	398.9	190.6	366.5	342.8	291.0
1978	425.8	336.2	192.4	458.2	210.1	523.4	565.8	388.8
Mean	337.3	212.3	171.8	352.4	207.6	384.4	451.7	302.5
4-yr Mean	390.5	255.4	204.2	409.8	238.9	445.8	516.5	352.0
Calcium:								
1974	15.2	10.0	10.5	14.3	12.7	15.5	19.0	13.9
1975	42.9	24.1	28.1	39.1	38.7	38.3	49.7	37.3
1976	41.7	32.7	41.2	38.9	44.7	42.5	55.1	42.3
1977	30.6	30.4	21.1	33.7	24.5	29.7	26.1	28.0
1978	31.8	37.5	27.2	34.6	31.0	37.3	48.3	35.4
Mean	32.5	26.9	25.7	32.2	30.2	32.6	39.7	31.4
4-yr Mean	36.7	31.1	29.3	36.5	34.7	37.0	44.8	35.7
Magnesium:								
1974	12.3	5.5	6.7	11.4	10.1	13.2	16.0	10.7
1975	32.0	14.8	19.9	30.0	30.4	31.9	41.3	28.6
1976	40.6	28.3	34.8	38.7	40.7	44.1	53.1	40.0
1977	26.8	22.1	17.6	31.4	22.9	28.8	22.7	24.5
1978	35.3	36.6	24.3	38.8	28.2	39.4	45.8	35.5
Mean	29.5	21.4	20.7	30.0	26.4	31.5	35.8	27.9
4-yr Mean	33.6	25.4	24.2	34.7	30.5	36.1	40.8	32.2

(Continued)

TABLE 3-5 (continued)

	Land slope							
	3-5%				8-10%			
Item	Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Chloride:	kg/ha							
1974	64.2	15.5	16.9	51.8	32.8	55.7	87.6	46.4
1975	120.7	50.3	51.8	134.5	67.0	137.9	149.1	101.6
1976	208.3	124.9	115.3	193.1	121.1	212.1	215.1	170.0
1977	151.9	69.0	57.3	173.9	66.0	142.4	124.7	112.2
1978	158.7	109.4	95.6	177.5	86.6	180.7	172.9	140.2
Mean	140.7	73.8	67.3	146.1	74.7	145.8	149.9	114.1
4-yr Mean	159.9	88.4	80.0	169.8	85.2	168.3	165.5	131.0

* 4 yrs = 1975, 1976, 1977 and 1978 (1974 started in August)

TABLE 8-6. YEARLY QUANTITIES OF MN, CU, ZN, FE AND NA REMOVED IN THE FORAGE

Item		Land slope							
		3-5%				8-10%			
		Lagoon effluent (672 kg N/ha)	Manure (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Ammonium nitrate (201 kg N/ha)	Lagoon effluent (672 kg N/ha)	Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)		(1)	(2)	(3)	(4)	(5)	(6)	(7)	
		kg/ha							
Maganese:	1974	0.17	0.09	0.08	0.17	0.22	0.28	0.28	0.19
	1975	0.45	0.25	0.18	0.54	0.74	0.66	0.69	0.50
	1976	0.44	0.50	0.34	0.55	1.33	0.67	1.20	0.72
	1977	0.38	0.63	0.18	0.41	0.73	0.53	0.59	0.49
	1978	0.34	0.96	0.27	0.47	1.22	0.63	0.73	0.66
	Mean	0.36	0.48	0.21	0.42	0.84	0.55	0.69	0.51
	4-yr* Mean	0.40	0.58	0.23	0.49	1.01	0.62	0.81	0.59
Copper:	1974	0.03	0.02	0.01	0.03	0.03	0.03	0.04	0.03
	1975	0.09	0.04	0.04	0.08	0.07	0.08	0.09	0.07
	1976	0.10	0.09	0.08	0.09	0.09	0.10	0.12	0.10
	1977	0.09	0.09	0.04	0.08	0.04	0.07	0.06	0.07
	1978	0.09	0.10	0.04	0.09	0.06	0.09	0.09	0.08
	Mean	0.08	0.07	0.04	0.07	0.06	0.08	0.08	0.07
	4-yr Mean	0.09	0.08	0.06	0.08	0.07	0.08	0.09	0.08
Zinc:	1974	0.14	0.09	0.08	0.14	0.13	0.18	0.27	0.14
	1975	0.38	0.23	0.22	0.37	0.37	0.44	0.57	0.37
	1976	0.49	0.56	0.37	0.47	0.48	0.57	0.84	0.54
	1977	0.39	0.65	0.23	0.42	0.30	0.41	0.41	0.40
	1978	0.49	0.78	0.27	0.53	0.46	0.57	0.72	0.55
	Mean	0.37	0.46	0.23	0.39	0.35	0.44	0.56	0.40
	4-yr Mean	0.44	0.56	0.28	0.45	0.40	0.49	0.64	0.46
Iron	1974	4.65	2.18	2.64	2.79	5.75	4.93	9.24	4.60
	1975	10.38	4.57	2.70	6.39	7.91	7.13	11.84	7.27
	1976	11.62	6.21	5.57	5.30	7.76	5.97	12.24	7.81
	1977	8.71	7.88	6.79	5.42	3.79	5.10	3.42	5.87
	1978	3.65	7.78	2.26	3.30	3.20	4.50	3.53	4.03
	Mean	7.80	5.73	4.00	4.64	5.68	5.52	8.06	5.92
	4-yr Mean	8.58	6.61	4.32	5.10	5.67	5.67	7.75	6.24

(Continued)

TABLE B-6 (continued)

Item	Land slope 3-5% Lagoon effluent (672 kg N/ha)	Land slope 3-5% Manure (672 kg N/ha)	Land slope 3-5% Ammonium nitrate (201 kg N/ha)	Land slope 3-5% Lagoon effluent (672 kg N/ha)	Land slope 8-10% Ammonium nitrate (201 kg N/ha	Land slope 8-10% Lagoon effluent (672 kg N/ha)	Land slope 8-10% Lagoon effluent (1345 kg N/ha)	Mean
(Treatment number)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
	kg/ha							
Sodium:								
1974	2.74	1.00	0.19	2.61	0.37	2.71	5.67	2.18
1975	7.39	1.65	0.85	7.19	2.40	9.09	15.59	6.31
1976	14.35	4.68	3.98	14.44	5.97	16.99	28.25	12.66
1977	15.13	8.08	2.92	16.39	6.53	15.95	16.35	11.62
1978	13.21	6.95	4.11	13.12	5.95	16.45	21.68	11.64
Mean	10.57	4.47	2.41	10.75	4.25	12.24	17.50	8.88
4-yr Mean	12.52	5.33	2.97	12.79	5.21	14.61	20.46	10.56

* 4 yrs = 1975, 1976, 1977 and 1978 (1974 started in August).

APPENDIX C

TABLES OF
SOIL CORE RESULTS
FOR EACH SAMPLING

TABLE C-1. EFFECT OF TREATMENTS ON SOIL NO_3-N

Date	Depth	Manure	Effluent Rate		Fertilizer N	Control
			Low	High		
	cm	ppm				
Dec. '75	0-15	6	9	20	4	1
	15-30	8	11	38	3	2
	30-45	6	11	44	2	2
	45-60	3	6	17	1	1
	60-75	1	3	6	1	1
	75-90	2	2	8	1	1
	90-105	2	2	4	1	1
	105-120	2	1	2	1	1
Feb. '76	0-15	4	7	12	4	6
	15-30	3	6	18	3	4
	30-45	4	7	34	3	3
	45-60	3	6	26	2	2
	60-75	3	4	8	2	2
	75-90	3	3	6	2	2
	90-105	3	3	4	2	2
	105-120	3	3	--	2	2
Feb. '77	0-15	35	7	13	5	6
	15-30	20	3	21	2	4
	30-45	22	3	27	4	2
	45-60	5	4	35	6	1
	60-75	3	4	27	4	1
	75-90	3	3	13	2	1
	90-105	3	3	4	2	1
	105-120	3	3	1	2	2
Mar. '78	0-15	29	9	10	4	8
	15-30	40	7	12	3	7
	30-45	35	9	40	2	2
	45-60	22	23	65	3	2
	60-75	1	17	73	3	1
	75-90	6	11	56	5	1
	90-105	5	6	34	5	2
	105-120	5	3	27	12	2
Dec. '78	0-15	35	12	17	4	9
	15-30	51	14	36	3	3
	30-45	41	17	60	2	2
	45-60	27	15	54	2	2
	60-75	11	13	45	3	2
	75-90	8	12	32	3	2
	90-105	9	9	25	3	2
	105-120	9	6	17	2	2
	120-135	8	4	10	2	2
	135-150	7	3	9	2	2
	150-165	6	4	7	2	2
	165-180	7	3	7	2	2
	180-195	7	3	6	1	3
	195-210	6	3	6	3	3

TABLE C-2. EFFECT OF TREATMENTS ON DILUTE ACID EXTRACTABLE SOIL P

Date	Depth	Manure	Effluent Rate		Fertilizer N	Control
			Low	High		
	cm	ppm				
Dec. '75	0-15	1	5	6	6	5
	15-30	1	4	8	3	1
	30-45	1	3	6	2	8
	45-60.	1	1	1	1	2
Feb. '76	0-15	2	7	7	1	3
	15-30	1	4	8	3	8
	30-45	2	3	8	3	3
	45-60	1	1	1	1	1
Feb. '77	0-15	1	15	34	4	5
	15-30	0	2	2	1	5
	30-45	0	1	1	0	0
	45-60	0	0	0	0	0
Mar. '78	0-15	14	30	98	13	3
	15-30	3	2	11	4	7
	30-45	1	1	1	1	1
	45-60	1	1	1	0	1
Dec. '78	0-15	13	35	74	10	5
	15-30	2	3	10	1	2
	30-45	1	1	1	1	0
	45-60	1	1	1	1	0

TABLE C 3. EFFECT OF TREATMENTS ON DILUTE ACID EXTRACTABLE SOIL K

Date	Depth	Manure	Effluent Rate		Fertilizer N	Control
			Low	High		
	cm	------------	------------	ppm	------------	------------
Dec. '75	0-15	80	205	317	66	68
	15-30	76	147	264	52	61
	30-45	76	108	187	54	46
	45-60	72	34	35	38	26
	60-75	53	32	41	47	22
	75-90	41	29	32	44	22
	90-105	35	27	28	38	25
	105-120	28	24	25	40	28
Feb. '76	0-15	88	163	288	40	61
	15-30	59	100	240	40	46
	30-45	69	84	166	44	44
	45-60	52	31	35	39	21
	60-75	42	27	33	44	20
	75-90	33	25	29	40	19
	90-105	27	26	24	38	23
	105-120	26	22	-	37	22
Feb. '77	0-15	88	274	308	30	84
	15-30	52	120	288	24	76
	30-45	72	72	160	28	--
	45-60	52	37	52	30	68
	60-75	40	29	32	42	40
	75-90	32	25	28	38	32
	90-105	28	23	24	34	32
	105-120	24	21	28	32	28
Mar. '78	0-15	130	393	462	57	82
	15-30	68	287	534	35	68
	30-45	80	104	412	50	98
	45-60	108	52	260	31	40
	60-75	64	63	112	26	28
	75-90	30	22	48	28	24
	90-105	22	21	28	30	30
	105-120	20	18	24	34	30
Dec. '78	0-15	109	356	468	43	89
	15-30	34	306	536	27	80
	30-45	40	164	432	24	50
	45-60	44	66	152	24	34
	60-75	44	43	75	31	25
	75-90	40	34	57	28	25
	90-105	34	26	37	31	28
	105-120	32	23	28	30	25
	120-135	28	23	23	30	23
	135-150	28	19	20	29	23
	150-165	23	20	23	27	23
	165-180	23	21	23	26	23
	180-195	23	19	23	27	25
	195-210	28	18	25	25	25

TABLE C-4. EFFECT OF TREATMENTS ON DILUTE ACID EXTRACTABLE SOIL CA

Date	Depth	Manure	Effluent Rate Low	Effluent Rate Hign	Fertilizer N	Control
	cm	ppm				
Dec. '75	0-15	926	550	398	722	504
	15-30	535	556	373	531	548
	30-45	306	519	433	492	476
	45-60	103	233	220	232	353
	60-75	44	85	85	41	147
	75-90	21	41	71	36	51
	90-105	23	35	54	56	36
	105-120	14	37	30	83	25
Feb. '76	0-15	586	558	540	733	526
	15-30	442	576	476	561	430
	30-45	364	583	560	548	414
	45-60	38	148	184	163	254
	60-75	38	52	44	106	118
	75-90	34	30	24	44	44
	90-105	20	23	10	32	18
	105-120	52	13	--	18	16
Feb. '77	0-15	536	608	468	644	496
	15-30	328	468	428	492	280
	30-45	328	468	368	412	420
	45-60	68	300	312	212	380
	60-75	24	116	144	108	280
	75-90	16	48	40	50	152
	90-105	16	32	8	36	112
	105-120	8	32	8	40	40
Mar. '78	0-15	736	564	668	685	464
	15-30	472	489	698	499	294
	30-45	268	506	462	400	376
	45-60	94	351	410	120	292
	60-75	52	152	586	217	198
	75-90	36	62	344	125	86
	90-105	28	37	174	63	30
	105-120	20	23	66	37	25
Dec. '78	0-15	788	581	540	560	536
	15-30	472	478	428	470	416
	30-45	320	480	444	382	420
	45-60	140	324	376	266	176
	60-75	72	173	176	154	56
	75-90	64	86	64	80	12
	90-105	48	65	96	58	4
	105-120	48	32	52	44	12
	120-135	40	25	32	30	4
	135-150	48	24	20	24	12
	150-165	32	20	24	24	24
	165-180	44	15	24	36	24
	180-195	28	20	4	24	12
	195-210	32	20	8	28	16

TABLE C-5. EFFECT OF TREATMENTS ON DILUTE ACID EXTRACTABLE SOIL MG

Date	Depth	Manure	Effluent Rate Low	Effluent Rate High	Fertilizer N	Control
	cm	ppm				
Dec. '75	0-15	418	162	98	229	148
	15-30	275	200	126	209	168
	30-45	212	200	155	207	190
	45-60	98	145	109	150	170
	60-75	68	81	64	52	101
	75-90	45	49	60	54	46
	90-105	33	38	41	71	38
	105-120	28	28	27	68	27
Feb. '76	0-15	254	157	138	238	124
	15-30	252	198	150	201	158
	30-45	220	209	186	220	174
	45-60	90	114	102	111	142
	60-75	70	69	50	99	88
	75-90	52	42	32	50	44
	90-105	42	38	18	41	28
	105-120	38	23	--	37	26
Feb. '77	0-15	244	172	104	200	96
	15-30	216	176	144	200	64
	30-45	192	188	128	212	168
	45-60	80	152	124	150	176
	60-75	40	84	80	92	164
	75-90	32	44	32	52	108
	90-105	28	32	12	36	84
	105-120	24	28	12	30	40
Mar. 78	0-15	254	122	128	191	110
	15-30	248	164	118	177	74
	30-45	228	184	146	168	142
	45-60	116	171	226	90	142
	60-75	60	93	146	104	108
	75-90	40	51	86	75	56
	90-105	32	28	54	50	18
	105-120	28	16	44	32	12
Dec. '78	0-15	244	134	120	136	108
	15-30	212	149	104	158	124
	30-45	180	165	136	158	160
	45-60	124	144	148	138	96
	60-75	68	103	84	90	48
	75-90	52	61	56	58	24
	90-105	44	47	52	48	12
	105-120	44	29	44	53	3
	120-135	36	23	52	28	8
	135-150	36	21	72	24	4
	150-165	28	19	80	22	12
	165-180	32	20	84	26	12
	180-195	28	20	88	36	16
	195-210	32	26	98	46	20

TABLE C-6. EFFECT OF TREATMENTS ON DILUTE ACID EXTRACTABLE SOIL NA

Date	Depth	Manure	Effluent Rate Low	Effluent Rate High	Fertilizer N	Control
	cm	ppm				
Dec. '75	0-15	27	48	54	11	8
	15-30	24	54	66	12	11
	30-45	30	51	76	14	20
	45-60	26	35	57	15	17
	60-75	24	32	47	24	18
	75-90	23	28	38	18	14
	90-105	20	25	24	19	16
	105-120	16	19	15	19	16
Feb. '76	0-15	36	44	46	17	14
	15-30	36	53	64	18	15
	30-45	37	56	78	21	20
	45-60	35	47	74	31	28
	60-75	33	39	54	29	24
	75-90	29	35	42	28	21
	90-105	26	32	32	24	20
	105-120	24	27	--	22	20
Feb. '77	0-15	32	49	32	12	8
	15-30	36	57	64	12	4
	30-45	36	63	68	14	8
	45-60	32	57	92	18	12
	60-75	24	44	80	26	16
	75-90	20	33	48	24	16
	90-105	16	28	24	20	16
	105-120	12	24	12	18	12
Mar. '78	0-15	38	33	34	24	26
	15-30	47	46	49	23	18
	30-45	51	58	62	23	21
	45-60	52	63	112	34	28
	60-75	55	63	87	40	38
	75-90	53	50	76	39	36
	90-105	42	40	65	37	32
	105-120	42	28	51	36	35
Dec. '78	0-15	46	43	38	10	6
	15-30	41	72	77	26	8
	30-45	36	91	130	11	16
	45-60	32	98	139	14	20
	60-75	43	101	135	32	38
	75-90	36	82	135	31	32
	90-105	34	64	111	31	30
	105-120	32	47	62	29	28
	120-135	32	36	41	26	26
	135-150	30	39	41	22	24
	150-165	28	34	34	22	20
	165-180	28	29	34	22	24
	180-195	28	27	32	21	22
	195-210	30	27	34	21	24

TABLE C-7. EFFECT OF TREATMENTS ON DILUTE ACID EXTRACTABLE SOIL CU

Date	Depth	Manure	Effluent Rate Low	Effluent Rate High	Fertilizer N	Control
	cm	ppm				
Dec. '75	0-15	0.76	0.42	0.28	0.32	0.20
	15-30	0.64	0.45	0.48	0.36	0.28
	30-45	0.44	0.36	0.44	0.40	0.36
	45-60	0.52	0.35	0.36	0.40	0.44
	60-75	0.68	0.49	0.44	0.62	0.40
	75-90	0.84	0.53	0.44	0.48	0.48
	90-105	0.88	0.53	0.36	0.48	0.48
	105-120	1.00	0.61	0.44	0.40	0.72
Feb. '76	0-15	0.80	0.53	0.40	0.52	0.28
	15-30	0.60	0.56	0.60	0.60	0.44
	30-45	0.64	0.52	0.56	0.56	0.48
	45-60	0.76	0.59	0.48	0.62	0.44
	60-75	0.88	0.65	0.56	0.66	0.44
	75-90	0.96	0.71	0.52	0.68	0.36
	90-105	1.20	0.74	0.44	0.70	0.40
	105-120	1.32	0.73	--	0.72	0.48
Feb. '77	0-15	1.0	0.45	0.40	0.48	0.32
	15-30	0.48	0.53	0.52	0.46	0.40
	30-45	0.56	0.53	0.64	0.54	0.60
	45-60	0.56	0.45	0.40	0.46	0.28
	60-75	0.48	0.42	0.40	0.50	0.36
	75-90	0.64	0.47	0.40	0.58	0.36
	90-105	0.92	0.57	0.32	0.52	0.44
	105-120	0.92	0.63	0.40	0.52	0.48
Mar. '78	0-15	0.64	0.36	0.32	0.32	0.28
	15-30	0.60	0.48	0.44	0.40	0.36
	30-45	0.52	0.41	0.48	0.40	0.48
	45-60	0.56	0.38	0.56	0.48	0.28
	60-75	0.60	0.40	0.48	0.58	0.32
	75-90	0.72	0.44	0.36	0.62	0.28
	90-105	0.76	0.45	0.36	0.54	0.24
	105-120	0.96	0.52	0.48	0.52	0.24
Dec. '78	0-15	0.8	0.36	0.36	0.36	0.28
	15-30	0.6	0.42	0.56	0.44	0.40
	30-45	0.56	0.42	0.64	0.44	0.40
	45-60	0.6	0.47	0.56	0.48	0.40
	60-75	0.6	0.40	0.48	0.52	0.40
	75-90	0.76	0.47	0.56	0.46	0.40
	90-105	0.84	0.53	0.80	0.56	0.52
	105-120	0.96	0.52	0.92	0.64	0.48

TABLE C-8. EFFECT OF TREATMENTS ON DILUTE ACID EXTRACTABLE SOIL ZN

Date	Depth	Manure	Effluent Rate		Fertilizer N	Control
			Low	High		
	cm	ppm				
Dec. '75	0-15	12	5	6	8	11
	15-30	5	2	3	3	4
	30-45	3	3	5	6	3
Feb. '76	0-15	3	4	10	6	8
	15-30	1	3	4	5	3
	30-45	2	4	6	3	3
Feb. '77	0-15	8	5	14	6	11
	15-30	2	2	2	4	3
	30-45	10	5	10	2	6
Mar. '78	0-15	10	6	8	9	10
	15-30	2	2	3	1	2
	30-45	1	1	1	1	4
Dec. '78	0-15	6	7	6	6	11
	15-30	2	2	3	1	2
	30-45	2	1	1	1	1

TABLE C-9. EFFECT OF TREATMENTS ON SOIL pH

Date	Depth	Manure	Effluent Rate Low	Effluent Rate High	Fertilizer N	Control
	cm	ppm				
Dec. '75	0-15	6.2	6.3	6.2	6.3	6.3
	15-30	5.4	5.9	6.0	6.2	6.5
	30-45	4.8	5.6	5.8	5.5	6.2
	45-60	4.8	4.8	4.8	4.9	5.1
	60-75	4.9	4.9	4.9	4.8	4.9
	75-90	4.9	4.9	4.8	4.9	4.8
	90-105	4.9	4.9	4.9	4.9	4.9
	105-120	4.9	4.9	4.9	4.9	4.9
Feb. '76	0-15	5.8	6.4	6.4	6.3	6.3
	15-30	5.3	6.1	6.3	6.0	6.0
	30-45	5.1	5.6	5.9	5.4	5.5
	45-60	5.0	4.8	4.7	4.9	5.0
	60-75	5.1	5.0	4.9	4.8	5.0
	75-90	5.1	5.0	4.9	4.8	4.9
	90-105	5.0	5.0	5.0	4.8	4.8
	105-120	5.0	5.0	--	4.8	4.8
Feb. '77	0-15	5.0	5.7	6.2	5.3	5.9
	15-30	4.9	5.6	6.1	5.6	5.9
	30-45	4.9	5.4	5.8	5.3	5.8
	45-60	4.9	5.0	5.0	5.0	5.5
	60-75	4.9	4.9	4.8	5.0	5.1
	75-90	4.8	4.8	4.9	5.0	5.0
	90-105	4.8	4.8	4.8	5.0	4.9
	105-120	4.9	4.9	4.8	4.9	4.8
Mar. '78	0-15	5.6	6.6	6.5	5.6	5.0
	15-30	5.1	6.1	6.7	6.2	5.9
	30-45	4.7	5.3	5.6	5.4	5.7
	45-60	4.7	4.7	4.8	4.6	5.1
	60-75	4.5	4.6	4.5	4.8	5.0
	75-90	4.8	4.7	4.2	4.8	4.8
	90-105	4.8	4.8	4.6	4.7	4.7
	105-120	4.8	4.8	4.6	4.7	4.9
Dec. '78	0-15	5.8	6.4	6.3	5.5	5.4
	15-30	5.0	6.0	6.2	5.4	5.3
	30-45	4.4	5.2	5.5	4.8	4.9
	45-60	4.2	4.6	4.5	4.5	4.4
	60-75	4.2	4.4	4.3	4.4	4.3
	75-90	4.3	4.4	4.4	4.3	4.3
	90-105	4.2	4.5	4.6	4.3	4.4
	105-120	4.2	4.4	4.5	4.3	4.4
	120-135	4.2	4.3	4.5	4.2	4.5
	135-150	4.2	4.4	4.6	4.5	4.3
	150-165	4.2	4.4	4.6	4.5	4.4
	165-180	4.2	4.4	4.6	4.5	4.4
	180-195	4.3	4.4	4.6	4.4	4.4
	195-210	4.4	4.4	4.6	4.5	4.2

APPENDIX D

RAINFALL AND RUNOFF DATA

TABLE D-1. MONTHLY RAINFALL AND RUNOFF

			Rainfall runoff, cm								
Year	Month	Rainfall,# cm	Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
1975	July	31.6	-	-	3.62	2.28	0.07	0.58	0.89	6.58
	Aug.	2.4	-	-	0	0	0	0	0	0
	Sep.	24.2	-	-	0.34	0.36	0.14	0.56	0.06	0.03
	Oct.	4.5	-	-	0.04	0.08	0	0.13	0.02	0.66
	Nov.	9.4	-	-	0	0.33	0	0.36	2.81	2.02
	Dec.	12.6	1.34	0.95	0.76	0.43	0.01	0.40	0.19	0.02
1976	Jan.	9.7	1.38	>5.15§	0.80	2.29	1.40	1.01	0.72	1.26
	Feb.	3.4	1.56	1.56	0	0	0	0	0	0
	Total@	97.8	-	-	5.56	5.77	1.62	3.04	4.69	10.57
	Mar.	7.1	0	0	0.09	0.02	0	0.16	0	0
	Apr.	0.8	0	0	0	0	0	0	0	0
	May	13.7	0.06	0.09	0.26	0.51	0.19	0.20	0	0.22
	June	12.6	0	0	0.25	0.07	0.12	0.30	0	0.06
	July	3.5	0	0	0.02	0	0	0.03	0	0.02
	Aug.	6.2	0	0	0	0.02	0	0.01	0	0
	Sep.	9.5	0	0	0	0	0	0	0	0
	Oct.	14.5	>2.00	>2.00	M*	M	M	0	0	0
	Nov.	5.5	0	0	0	0.02	0	0	0	0
	Dec.	11.5	>2.42	>2.01	0.52	0.05	0.14	0	0.19	0.40
1977	Jan.	18.6	>2.91	>4.42	1.11	0.12	0.01	0	0.24	0.32
	Feb.	3.8	0	0	0	0	0	0	0	0
	Total	107.3	>7.39	>8.52	2.25‡	0.81‡	0.46‡	0.70	0.43	1.02

(continued)

TABLE D-1 (continued)

Year	Month	Rainfall,$^{\#}$ cm	Rainfall runoff, cm Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
1977	Mar.	15.7	>2.34	>4.00	2.42	0.81	0.05	0.06	0.78	0.40
	Apr.	5.8	0	0	0.22	0.18	0	0	0	0.26
	May	7.9	0	0	0	0	0	0.02	0	0
	June	1.4	0	0	0	0	0	0	0	0
	July	3.6	0	0	0	0.01	0	0	0	0
	Aug.	10.3	0	0	M	0	0	0	0.03	0.01
	Sep.	15.2	M	M	M	M	M	0.08	0.02	>1.52
	Oct.	13.5	>2.00	>2.00	0.03	0.03	0.08	0.01	0.08	0
	Nov.	7.7	>2.00	>2.00	M	>1.35	0.57	0.04	0.04	0
	Dec.	7.8	0	0.13	0	0.06	0	0	0	0
1978	Jan.	26.0	>10.0	>10.0	M	>1.50	>1.50	>0.33	>2.21	1.77
	Feb.	2.9	0	0	0	0	0	0	0	0
	Total	117.8	>16.34	>18.13	2.67$^{\neq}$	>3.94	>2.20	>0.54	>3.16	>3.96
	Mar.	10.3	>3.01	>4.82	2.38	1.98	1.46	1.88^{+}	1.87^{+}	1.96^{+}
	Apr.	18.6	>2.01	>2.10	3.42^{+}	4.23	3.96	1.92	3.41	3.39^{+}
	May	9.7	>4.01	>4.03	1.32	1.43	0.82	0.21	1.07	1.33
	June	9.2	IRG	0	0.02	0.13	IRG	0.02	IRG	IRG
	July	11.2	0.21	T	0.21	0.34	0.04	0.12	0.02	0.19
	Aug.	5.7	0	0	0.02	0.06	T	T	T	0.02
	Sep.	3.8	0	0	0.02	0.02	T	0.11	T	IRG
	Oct.	5.6	0	T	0.05	0.03	T	0.15	0.02	0.05
	Nov.	11.6	0.50	M	0.32	0.22	0.01	0.05	0.04	1.77^{+}
	Dec.	8.0	>2.46	M	0.99	0.90	0.36	0.02	0.72^{+}	1.47
1979	Jan.	12.6	>4.07	M	1.89	1.88	1.18	0.64	1.17	2.54
	Feb.	10.0	>8.00	M	3.21	4.26	1.13	1.11	2.86	5.27
	Total	116.3	>24.27	>10.95	13.85$^{\neq}$	15.48	8.96$^{\neq}$	6.23$^{\neq}$	11.18$^{\neq}$	17.99$^{\neq}$

(continued)

TABLE D-1 (continued)

[#] Rainfall is total rain for all events, including those without runoff.

[§] Volumes with ">" (greater than) indicate that the sample collection container overflowed. This was possible with Tmt. 1A and Tmt. 1B throughout the entire period, and was possible for the other treatments Nov. 1977 - Feb. 1978.

[@] Totals are for the water year March to March except for the first year (1975) when data began in July for all treatments except 1A and 1B which did not have runoff data until December.

[*] M indicates that runoff occurred but sampler malfunctioned, resulting in no accurate measure of runoff volume.

[+̸] Volume sums which may have been larger due to irrigation-rainfall mixed runoff, estimations of runoff volumes, or malfunctions in equipment.

[+] Volumes which include events where runoff volume was estimated from volume of sample collected or from the runoff volumes for the other plots.

TABLE D-2. RAINFALL AND RUNOFF

Date	Rainfall,* cm	Rainfall runoff, cm							
		Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
750711	1.19								
13	6.12			0.44	0.39	0.07	0.22	0.14	0.77
14	11.63			0.46	1.51		0.17	0.33	3.08
15	0.86			0.08	0.19			0.33	0.14
16	4.34			2.60	0.19		0.15	0.09	2.59
18	1.40			0.04			0.04		
Total	25.54			3.62	2.28	0.07	0.58	0.89	6.58
750807	1.65								
Total	1.65			0	0	0	0	0	0
750901	2.29			0.01	0.02		0.03		
13	2.16			0.01					
22	4.14			0.04					
23	2.59								
24	2.34				0.01		0.06		
25	5.46			0.26	0.18	0.06	0.36	0.01	0.03
26	2.44			0.02	0.15	0.08	0.11	0.05	IRG
Total	21.42			0.34	0.36	0.14	0.56	0.06	0.03
751009	2.03			0.02	0.04		0.01		0.07
17	1.17								0.17
18	1.32			0.02	0.04		0.12	0.02	0.42
Total	4.52			0.04	0.08	0	0.13	0.02	0.66
751110	0.79						0.09		
13	5.66				0.28		0.12	2.80	2.02
24	2.46				0.05		0.15	0.01	
Total	8.91			0	0.33	0	0.36	2.81	2.02

(continued)

TABLE D-2 (continued)

Date	Rainfall,* cm	Rainfall runoff, cm Tmt 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
751201	1.04								
08	2.29			0.02	0.02	0.01	0.02	0.02	
18	1.98								
26	3.63			0.74			0.11		
30	1.45	0.14	0.89		0.06		0.12	0.03	0.02
31	1.14	1.20	0.06		0.35		0.15	0.14	
Total	11.53	1.34	0.95	0.76	0.43	0.01	0.40	0.19	0.02
760101	1.22	0.58	1.20	0.10	0.41		0.50	0.44	0.43
07	1.24						0.02	0.04	
08	1.55	0.18	>1.20				0.05		0.08
26	1.02						0.04	0.03	
27	2.82	0.11	>1.20		0.56	0.05	0.28	0.21	0
28	1.14	0.51	1.55	0.70	1.32	1.35	0.12		0.75
Total	8.99	1.38	>5.15	0.80	2.29	1.40	1.01	0.72	1.26
760202	2.90	1.56	1.56						
Total	2.90	1.56	1.56	0	0	0	0	0	0
760309	1.35						0.03		
13	0.91						0.02		
16	2.24			0.09	0.02		0.11		
30	1.22			T					
Total	5.72	0	0	0.09	0.02	0	0.16	0	0
760401				T					
Total	0	0	0	0	0	0	0	0	0

(continued)

TABLE D-2 (continued)

Date	Rainfall,* cm	Rainfall runoff, cm							
		Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
760501	2.39								
08	0.56				0.02				
16	4.60	0.06	0.09	0.14	0.30	0.06	0.10		0.06
30	3.86			0.12	0.19	0.13	0.10		0.16
Total	11.41	0.06	0.09	0.26	0.51	0.19	0.20	0	0.22
760603	2.59			0.04	0.03	0.04	0.10		
04	1.09		IRG	0.06	0.02	IRG	0.04		
05	0.36			0.02	0.01	0.01			
17	4.42			0.10		0.07	0.16		0.01
20	0.79			0.03	0.01				0.05
21	1.90								
28	1.42								
Total	12.57	0	0	0.25	0.07	0.12	0.30	0	0.06
760701	1.47			0.02			0.03		0.02
31	0.74								
Total	2.21	0	0	0.02	0	0	0.03	0	0.02
760803	2.31				0.02		0.01		
08	1.27								
22	1.68								
Total	5.26	0	0	0	0.02	0	0.01	0	0
760903	1.09								
11	2.11								
15	4.09								
27	1.83								
Total	9.12	0	0	0	0	0	0	0	0

(continued)

TABLE D-2 (continued)

Date	Rainfall,* cm	Rainfall runoff, cm							
		Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
761009	3.12								
17	1.14								
20	8.05	>2.00	>2.00	M	M	M			
31	1.19								
Total	13.50	>2.00	>2.00	-	-	-	0	0	0
761115	1.50								
16	0.56	T	T						
29	1.78				0.02				
Total	3.84	0	0	0	0.02	0	0	0	0
761207	2.11		M	0.08	0.02				
08	2.11	0.42	M	0.28		0.01			0.19
12	3.56	>2.00	>2.00	0.16		0.13		0.19	0.21
16	1.17				0.03				
27	1.09		0.01						
Total	10.04	>2.42	>2.01	0.52	0.05	0.14	0	0.19	0.40
770107	1.14								
10	3.76	>2.0	>2.0	1.11	0.10	0.01	0	0.24	0.19
14	0.84	0.07	0.42						
15	0.56	0.84	>2.0		0.02				0.13
Total	6.30	>2.91	>4.42	1.11	0.12	0.01	0	0.24	0.32
7702									
Total	0	0	0	0	0	0	0	0	0

(continued)

TABLE D-2 (continued)

Date	Rainfall,* cm	Rainfall runoff, cm							
		Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
770305	1.55	M	M						
07	3.30	>2.0	>2.0	1.02	0.16	0.02		0.14	0.20
13	4.39	0.34	>2.0	1.38	0.62	0.03	0.06	0.64	0.18
20	1.37								
22	2.13			0.02	0.02				0.02
30	2.92			T	0.01				
Total	15.66	>2.34	>4.00	2.42	0.81	0.05	0.06	0.78	0.40
770405	2.08			0.22	0.18				0.26
Total	2.08	0	0	0.22	0.18	0	0	0	0.26
770520	1.37						0.02		
25	2.62								
26	2.31				T				
Total	6.30	0	0	0	T	0	0.02	0	0
7706									
Total	0	0	0	0	0	0	0	0	0
770722	1.88			T	0.01				
Total	1.88	0	0	T	0.01	0	0	0	0
770802	1.09								
16	1.22								
18	6.65			M				0.03	0.01
Total	8.96	0	0	M	0	0	0	0.03	0.01

(continued)

TABLE D-2 (continued)

Date	Rainfall,* cm	Rainfall runoff, cm Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
770908	13.72	M	M	M	M	M	0.08	0.02	>1.52
17	1.32								
Total	15.04	M	M	M	M	M	0.08	0.02	>1.52
771010	1.02								
13	2.72								
14	2.21								
26	5.99	>2.0	>2.0	0.03	0.03	0.08	0.01	0.08	
Total	11.94	>2.0	>2.0	0.03	0.03	0.08	0.01	0.08	0
771104	1.40				0.02				
07	4.37	>2.0	>2.0	M	>1.33	0.57	0.04	0.04	T
25	1.32								
Total	7.09	>2.0	>2.0	M	>1.35	0.57	0.04	0.04	T
771215	2.13					T			
21	1.80		0.13		0.05				
31	1.02	T	T		0.01				
Total	4.95	T	0.13	0	0.06	T	0	0	0
780107	1.68		0.01						
09	2.77	>2.0	>2.0	M	M	M		0.07	0.60
14	4.39	>2.0	>2.0	M	M	M	M	0.94	0.91
18	2.03	>2.0	>2.0	M	0.17	0.27	0.16		
20	4.27	>2.0	>2.0		>1.33	>1.23		1.08	
26	3.05	>2.0	>2.0	M	M	M	0.17	M	0.26
Total	18.19	>10.0	>10.1	-	>1.50	>1.50	>0.33	>2.09	1.77

(continued)

TABLE D-2 (continued)

Date	Rainfall,* cm	Rainfall runoff, cm							
		Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
780224	0.81								
Total	0.81	0	0	0	0	0	0	0	0
780301	0.71		0.71	M			M	M	M
06	1.47§	0.90	>2.00	M	0.19	0.01	M	M	M
09	0.56			T	T	T	T		
10	4.01	>2.00	>2.00	2.35	1.71	1.44	1.83^{+}	1.83^{+}	1.83^{+}
13	0.23	0.05	0.06	0.02	0.03	T	T	0.02^{+}	0.02^{+}
27	3.07	0.06	0.05	0.01	0.05	0.01	0.05	0.02	0.11
Total	10.05	>3.01	>4.82	2.38	1.98	1.46	1.88^{+}	1.87^{+}	1.96^{+}
780412	0.25			T	0.01	T	T	T	IRG
13	0.76				0.02	T	T		
18	0.71			T	0.01	T	T		0.01
19	3.35	0.01	0.10	0.09	0.08	0.02	0.04	0.07	0.11
20	0.36			T	T	T	T	T	
26	12.17	>2.00	>2.00	3.27^{+}	4.01	3.93	1.87	3.29	3.27^{+}
27	0.74	M	M	0.06^{+}	0.10	0.01	0.01	0.05	T
Total	18.34	>2.01	>2.10	3.42^{+}	4.23	3.96	1.92	3.41	3.39^{+}
780501	0.23				T		T		
04	2.08	0.01	0.03	0.01	0.01	T	0.01		0.01
05	0.43	IRG	IRG			T			IRG
08	4.27	>2.00	>2.00	1.29	1.37	0.82	0.20	1.05	1.29
09	0.46	>2.00	>2.00	0.02	0.04	T	T	0.02	0.02
15	1.40			T	0.01		T		0.01
16	0.74			T			T		
Total	9.61	>4.01	>4.03	1.32	1.43	0.82	0.21	1.07	1.33

(continued)

TABLE D-2 (continued)

Date	Rainfall,* cm	Rainfall runoff, cm							
		Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
780605	0.94			T	T	T	T		
06	0.48				T		T		
07	1.07			T	T	T	T		T
08	0.53			T	T		T		T
09	4.57	IRG		0.02	0.11	IRG	0.02	IRG	IRG
27	1.19			T	0.02	T	T	T	
Total	8.78	IRG	0	0.02	0.13	IRG	0.02	IRG	IRG
780711	2.74			0.02	0.02	0.01	0.03	T	
15	0.66			T	0.01	0.01	T		
16	5.44	0.21	T	0.18	0.30	0.02	0.05	0.01	0.19
25	1.60			0.01	0.01	T	0.04	0.01	T
26	0.36			T	T	T	T		
28	0.30				T	T	T		
Total	11.10	0.21	T	0.21	0.34	>0.04	0.12	0.02	0.19
780801	0.51			T	0.01	T	T	T	
02	0.25			T	T	T	T	T	
03	1.30			T	0.02	T	T		
06	0.36			T	0.01	T	T		
07	1.70			0.02	0.01	T	T		0.02
08	0.43			T			T	T	
10	0.66			T	0.01		T	T	
30	0.18			T	T		T		
Total	5.39	0	0	0.02	0.06	T	T	T	0.02

(continued)

TABLE D-2 (continued)

Date	Rainfall,* cm	Rainfall runoff, cm Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg.
780901	1.02			0.01	0.01	T	0.04	T	IRG
05	0.71			T	T		0.01		
11	1.73			0.01	0.01	T	0.06	T	T
23	0.33			T	T		T		
Total	3.79	0	0	0.02	0.02	T	0.11	T	IRG
781001	4.44			0.04	0.03	T	0.14	0.02	0.05
05	0.71			0.01	T	T	0.01		T
28	0.48		T	T	T		T	T	
Total	5.63	0	T	0.05	0.03	T	0.15	0.02	0.05
781106	0.51			T	T		T		
08	3.86	T		0.05	0.03	T	0.02	0.01	0.69
10	0.25			T	T		T		IRG
11	0.51			T	T	T	T	T	
17	0.33				T		T		
18							T		
24	0.89			T	T	T	T	T	
28	2.18	T		0.01	0.01	T	0.01	0.01	T
30	2.87	0.50		0.26	0.18	0.01	0.02	0.02	1.08^{+}
Total	11.50	0.50	-	0.32	0.22	0.01	0.05	0.04	$>1.77^{+}$
781204	0.15				0.01	T	T	T	
05	4.14	>2.00		0.96	0.77	0.36	0.02	0.70^{+}	1.41
06	0.18	0.46		0.03	0.11	T	T	0.02	0.06
10	0.71			T	T	T	T	T	T
18	1.02	T		T	0.01	T	T	T	
21	0.46			T	T	T	T		
27	1.40								
Total	8.06	>2.46	-	0.99	0.90	0.36	0.02	0.72^{+}	1.47

(continued)

TABLE D-2 (continued)

Date	Rainfall,[*] cm	Rainfall runoff, cm							
		Tmt. 1A Low irg.	Tmt. 1B Low irg.	Tmt. 2 Manure	Tmt. 3 Fert.	Tmt. 4 Low irg.	Tmt. 5 Fert.	Tmt. 6 Low irg.	Tmt. 7 High irg
790102	1.73			T	0.01	T	0.01	T	0.01
03	0.13			T	T	T	T		T
08	1.47	0.03		T	0.01	0.01	0.01	T	0.02
14	2.82	>2.00		0.19	0.38	0.02	0.01	0.05	0.90
22	5.23	>2.00		1.69	1.45	1.15	0.61	1.11	1.57
25	1.04	0.04		0.01	0.04	T	T	0.01	0.05
28	0.20			T	T		T		
Total	12.62	>4.07	-	1.89	1.88	1.18	0.64	1.17	2.54
790201	0.28[§]				T		T		
14	1.62[§]				0.01	T	T		
22	1.90[§]	>2.00		0.62	1.13	0.16	0.06	0.50	1.78
23	1.37	>2.00		0.35	0.51	0.13	0.07	0.35	0.77
24	1.85	>2.00		0.78	1.00	0.23	0.30	0.75	1.05[+]
26	3.02	>2.00		1.46	1.61	0.61	0.68	1.26	1.67[+]
Total	10.04	>8.00	-	3.21	4.26	1.13	1.11	2.86	5.27[+]

[*] Rainfall events less than 1 cm. are not included unless runoff occurred.

M - Malfunction in apparatus or sampler disconnected, and no volume estimated.

IRG - Runoff occurring within 12 hours of irrigation and thought to include irrigation liquid runoff mixed with rainfall runoff.

T - Trace of runoff; less than 0.005 cm.

[§] Snow event or freezing rain. Precipitation may have occurred 1 to 5 days before, and the amounts are measured with rain gage. Date is for day runoff was recorded and sample taken.

[+] Runoff measurement apparatus malfunctioned and runoff volume was estimated from the volume of sample collected or from the runoff volumes of other plots.

TABLE D-3. MONTHLY RUNOFF, MEAN AND HIGHEST CONCENTRATIONS, AND MASS TRANSPORT FOR MARCH 1978 - FEB. 1979 FOR TKN

		Highest concentration event			Mean conc., mg/ℓ			
Tmt.	Month	Conc., mg/ℓ	Volume, cm	n†	Arith.	Vol.-wt.	Runoff, cm	Mass, Kg/ha
Fert. (#3)	Mar.	3.0	0.03	4	2.6	2.4	1.98	0.48
	Apr.	11.7	0.01	6	5.2	4.3	4.23	1.81
	May	6.9	0.01	4	4.5	2.6	1.43	0.38
	June	3.2	0.02	2	2.7	2.2	0.13	0.03
	July	6.4	0.02	4	3.4	2.3	0.34	0.08
	Aug.	3.1	0.01	5	2.2	2.1	0.06	0.01
	Sept.	8.6	0.01	2	6.0	5.7	0.02	0.01
	Oct.	1.9	0.03	1	1.9	1.9	0.03	0.01
	Nov.	3.4	0.18	3	2.7	3.2	0.22	0.07
	Dec.	11.3	0.01	4	5.0	2.7	0.90	0.24
	Jan.	2.7	1.44	5	1.8	2.6	1.88	0.49
	Feb.	3.9§	0.01	5	3.1	2.7	4.26	1.13
	Mar.-Feb.	11.7	0.01	45	3.5*	3.1‡	15.48	4.74
Fert. (#5)	Mar.	5.9	0.05	2	4.1	2.5	1.88^{+}	0.47
	Apr.	5.5	0.01	3	4.2	3.0	1.92	0.58
	May	6.0	0.01	2	4.4	3.0	0.21	0.06
	June	3.3	0.02	1	3.3	3.3	0.02	0.01
	July	10.8	0.03	3	6.2	5.7	0.12	0.07
	Aug.	-	0	0	-	-	0	0
	Sept.	18.4	0.04	3	11.4	12.3	0.11	0.13
	Oct.	5.2	0.14	2	3.8	5.1	0.15	0.08
	Nov.	3.0	0.02	3	2.7	2.8	0.05	0.01
	Dec.	2.6	0.02	1	2.6	2.6	0.02	0
	Jan.	2.6	0.61	4	1.8	2.6	0.64	0.16
	Feb.	3.7§	0.06	4	3.0	2.7	1.11	0.30
	Mar.-Feb.	18.4	0.03	28	4.4	3.0	6.23	1.88

(continued)

TABLE D-3 (continued)

Tmt.	Month	Highest concentration event: Conc., mg/ℓ	Highest concentration event: Volume, cm	n[†]	Mean conc., mg/ℓ: Arith.	Mean conc., mg/ℓ: Vol.-wt.	Runoff, cm	Mass, Kg/ha
Low irg. (#4)	Mar.	10.2	0.01	3	6.3	2.6	1.46	0.38
	Apr.	6.0	0.02	3	4.8	4.4	3.96	1.74
	May	3.3	0.82	1	3.3	3.3	0.82	0.27
	June	-	0	0	-	-	0	0
	July	22.0	0.01	3	11.7	10.6	0.04	0.03
	Aug.	-	0	0	-	-	0	0
	Sept.	-	0	0	-	-	0	0
	Oct.	-	0	0	-	-	0	0
	Nov.	6.3	0.01	1	6.3	6.3	0.01	0.01
	Dec.	4.1	0.36	1	4.1	4.1	0.36	0.15
	Jan.	8.9	0.01	3	6.2	4.7	1.18	0.56
	Feb.	4.5[§]	0.12	4	3.5	3.4	1.13	0.38
	Mar.-Feb.	22.0	0.01	19	6.0	3.9	8.96	3.51
Low irg. (#6)	Mar.	5.9	0.02	3	4.0	2.6	1.87[+]	0.49
	Apr.	2.9	0.07	3	2.9	2.9	3.41	0.98
	May	3.4	1.05	2	3.2	3.4	1.07	0.36
	June	-	0	0	-	-	0	0
	July	12.7	0.01	2	9.0	9.4	0.02	0.01
	Aug.	-	0	0	-	-	0	0
	Sept.	-	0	0	-	-	0	0
	Oct.	36.0	0.02	1	36.0	36.0	0.02	0.06
	Nov.	7.7	0.01	3	5.6	5.4	0.04	0.02
	Dec.	6.0	0.70	2	5.6	6.0	0.72[+]	0.43
	Jan.	21.9	0.05	3	13.2	4.7	1.17	0.54
	Feb.	7.2[§]	0.50	4	5.2	4.6	2.86	1.30
	Mar.-Feb.	36.0	0.02	23	7.4	3.8	11.18	4.20

(continued)

TABLE D-3 (continued)

		Highest concentration event			Mean conc., mg/ℓ			
Tmt.	Month	Conc., mg/ℓ	Volume, cm	n[†]	Arith.	Vol.-wt.	Runoff, cm	Mass, Kg/ha
Manure (#2)	Mar.	4.8	0.01	3	4.0	2.8	2.38	0.67
	Apr.	11.9	3.27	3	9.2	11.7	3.42[+]	4.00
	May	7.8	0.02	3	5.8	7.5	1.32	0.99
	June	2.6	0.02	1	2.6	2.6	0.02	0.01
	July	2.4	0.18	3	1.8	2.2	0.21	0.05
	Aug.	1.6	0.02	1	1.6	1.6	0.02	0
	Sept.	10.1	0.01	2	7.0	6.6	0.02	0.01
	Oct.	3.0	0.04	2	2.7	2.9	0.05	0.01
	Nov.	5.0	0.26	3	2.9	4.5	0.32	0.14
	Dec.	9.0	0.03	2	7.4	6.0	0.99	0.59
	Jan.	4.8	0.01	3	3.1	1.5	1.89	0.28
	Feb.	26.4[§]	0.78	4	9.7	9.0	3.21	2.89
	Mar.-Feb.	26.4	0.78	30	5.2	7.0	13.85	9.65
High irg. (#7)	Mar.	14.3	0.11	3	8.5	5.3	1.96[+]	1.05
	Apr.	7.8	3.27	3	6.4	7.8	3.39[+]	2.63
	May	17.9	0.01	4	10.4	5.6	1.33	0.74
	June	–	0	0	–	–	0	0
	July	4.4	0.19	1	4.4	4.4	0.19	0.09
	Aug.	3.2	0.02	1	3.2	3.2	0.02	0
	Sept.	–	0	0	–	–	0	0
	Oct.	11.4	0.05	1	11.4	11.4	0.05	0.06
	Nov.	8.8	0.69	2	7.7	7.5	1.77[+]	1.33
	Dec.	9.8	0.06	2	7.6	5.6	1.47	0.82
	Jan.	11.9	0.01	5	6.5	4.2	2.54	1.07
	Feb.	6.2[§]	0.77	4	5.0	4.8	5.27[+]	2.55
	Mar.-Feb.	17.9	0.01	26	7.3	5.7	17.99	10.34

(continued)

TABLE D-3(continued)

Tmt.	Month	Highest concentration event Conc., mg/ℓ	 Volume, cm	n[†]	Mean conc., mg/ℓ Arith.	 Vol.-wt.	Runoff, cm	Mass, Kg/ha
Low irg. (1A)	Mar.	5.1	0.05	3	4.0	3.2	>3.01	>0.97
	Apr.	30.6	0.01	2	18.9	7.3	>2.01	>1.45
	May	9.3	0.01	3	7.7	6.8	>4.01	>2.73
	June	–	0	0	–	–	0	0
	July	3.1	0.21	1	3.1	3.1	0.21	0.06
	Aug.	–	0	0	–	–	0	0
	Sept.	–	0	0	–	–	0	0
	Oct.	–	0	0	–	–	0	0
	Nov.	7.7	0.50	1	7.7	7.7	0.50	0.38
	Dec.	6.2	0.46	2	5.8	5.7	>2.46	>1.39
	Jan.	7.9	0.04	4	5.2	5.0	>4.07	>2.04
	Feb.	7.0[§]	>2.00	4	5.6	5.6	>8.00	>4.46
	Mar.-Feb.	30.6	0.01	20	6.9	5.6	>24.27	13.49
Low irg. (#1B)	Mar.	7.2	0.05	5	4.4	3.9	>4.82	>1.86
	Apr.	6.7	0.10	2	6.3	6.0	>2.10	>1.26
	May	68.0	0.03	3	25.9	5.3	>4.03	>2.13
	June	–	0	0	–	–	0	0
	July	–	0	0	–	–	0	0
	Aug.	–	0	0	–	–	0	0
	Sept.	–	0	0	–	–	0	0
	Oct.	–	0	0	–	–	0	0
	Nov.	–	M	–	–	–	–	–
	Dec.	–	M	–	–	–	–	–
	Jan.	–	M	–	–	–	–	–
	Feb.	–	M	–	–	–	–	–
	Mar.-Feb.	68.0	0.03	10	11.2	4.8	>10.95	>5.25

[†] n = Number of runoff events.

TABLE D-3 (continued)

[*] Arithmetic mean concentration for period Mar.-Feb. is the average for all events, not the average of monthly means.

[≠] Volume-weighted concentration for period Mar.-Feb. is calculated from the total mass divided by total volume.

[+] Runoff volume estimated from sample volume or from runoff volumes of other plots.

[§] Runoff from melting snow or rain within two days after snow melted.

TABLE D-4. MONTHLY MEANS AND HIGHEST CONCENTRATION FOR MARCH 1978 - FEB. 1979 FOR P

	Tmt. 3 (fertilizer)					Tmt. 5 (fertilizer)				
	Highest conc. event			Mean concentration		Highest conc. event		n	Mean concentration	
Month	Conc., mg/ℓ	Volume, cm	n*	Arith.	Vol.-wt.	Conc., mg/ℓ	Volume, cm		Arith.	Vol.-wt.
				-------mg/ℓ-------					------mg/ℓ---------	
Mar.	0.5	0.03	4	0.4	0.4	4.0	0.05	2	2.2	0.5
Apr.	2.7	0.10	6	0.9	1.0	1.3	0.01	3	1.0	0.8
May	1.4	0.01	4	0.9	0.6	0.7	0.01	2	0.7	0.6
June	0.4	0.02	2	0.3	0.3	0.6	0.02	1	0.6	0.6
July	0.8	0.02	4	0.4	0.4	2.2	0.03	3	1.4	1.3
Aug.	0.4	0.01	5	0.3	0.3	-	-	0	-	-
Sept.	1.0	0.01	2	0.6	0.6	5.3	0.04	3	2.7	3.0
Oct.	0.3	0.03	1	0.3	0.3	1.6	0.14	2	1.0	1.6
Nov.	0.6	0.18	3	0.5	0.6	0.8	0.01	3	0.7	0.7
Dec.	1.6	0.01	4	0.8	0.6	0.6	0.02	1	0.6	0.6
Jan.	0.6	1.44	5	0.3	0.6	0.5	0.61	4	0.3	0.5
Feb.	1.6§	0.51	5	0.7	0.5	0.5§	0.06	4	0.4	0.3
			45					28		
	Tmt. 4 (low irrigation)					Tmt. 6 (low irrigation)				
Mar.	2.2	0.01	3	1.3	0.8	1.2	0.02	3	1.1	1.2
Apr.	1.9	0.02	3	1.3	1.1	1.2	3.29	3	0.9	1.2
May	1.5	0.82	1	1.5	1.5	1.7	1.05	2	1.4	1.7
June	-	-	0	-	-	-	-	0	-	-
July	16.8	0.01	3	7.6	6.8	1.5	0.01	2	1.4	1.4
Aug.	-	-	0	-	-	-	-	0	-	-
Sept.	-	-	0	-	-	-	-	0	-	-
Oct.	-	-	0	-	-	15.4	0.02	1	15.4	15.4
Nov.	4.0	0.01	1	4.0	4.0	9.1	0.01	3	4.9	4.7
Dec.	2.2	0.36	1	2.2	2.2	2.8	0.70	2	2.7	2.6
Jan.	2.2	0.01	3	1.9	1.8	4.2	0.01	3	3.1	2.8
Feb.	1.6	0.16§	4	1.4	1.3	2.5§	0.75	4	2.2	2.1
			19					23		

(continued)

TABLE D-4 (continued)

	Tmt. 2 (manure)					Tmt. 7 (high irrigation)				
	Highest conc. event		n	Mean concentration		Highest conc. event		n	Mean concentration	
Month	Conc., mg/ℓ	Volume, cm		Arith.	Vol.-wt.	Conc., mg/ℓ	Volume, cm		Arith.	Vol.-wt.
				------mg/ℓ--------					------mg/ℓ--------	
Mar.	2.2	0.02	3	1.6	2.2	7.8	0.11	3	4.2	2.6
Apr.	8.4	3.27	3	5.5	8.2	6.1	3.27	3	4.0	5.1
May	7.6	1.29	3	5.1	7.5	6.0	0.02	4	4.9	5.7
June	0.6	0.02	1	0.6	0.6	-	-	0	-	-
July	0.8	0.02	3	0.7	0.7	2.2	0.19	1	2.2	2.2
Aug.	0.3	0.02	1	0.3	0.3	1.9	0.02	1	1.9	1.9
Sept.	1.2	0.01	2	0.9	0.9	-	-	0	-	-
Oct.	0.6	0.04	2	0.5	0.6	10.7	0.05	1	10.7	10.7
Nov.	4.5	0.26	3	1.8	3.8	18.8	0.69	2	16.2	15.6
Dec.	14.5	0.96	2	11.1	14.2	12.9	0.06	2	11.4	10.0
Jan.	6.3	1.69	3	5.1	6.3	8.2	0.01	5	6.6	5.9
Feb.	5.4[§]	0.35	4	4.4	4.0	5.2[§]	0.77	4	4.5	4.3
			30					26		

---

[*] n = number of runoff events.

[§] Runoff from melting snow or rain within two days after snow melted.

TABLE D-5. MONTHLY MEANS AND HIGHEST CONCENTRATION FOR MARCH 1978 - FEB. 1979 FOR NO_3-N

	Tmt. 3 (fertilizer)					Tmt. 5 (fertilizer)				
	Highest conc. event		*	Mean concentration		Highest conc. event		n	Mean concentration	
Month	Conc., mg/ℓ	Volume, cm	n	Arith.	Vol.-wt.	Conc., mg/ℓ	Volume, cm		Arith.	Vol.-wt.
				-------mg/ℓ-------					-------mg/ℓ-------	
Mar.	2.0	0.05	4	0.9	0.4	2.8	0.05	2	1.6	0.4
Apr.	8.4	4.00	6	3.4	8.1	1.8	0.04	3	1.7	1.6
May	4.3	0.01	4	1.4	0.6	1.3	0.01	2	0.9	0.5
June	2.2	0.02	2	1.9	1.7	1.3	0.02	1	1.3	1.3
July	3.0	0.02	4	1.9	1.1	5.6	0.03	3	3.8	3.6
Aug.	1.9	0.01	5	1.1	0.9	-	-	0	-	-
Sept.	2.7	0.01	2	2.2	2.1	11.9	0.06	3	7.7	9.1
Oct.	1.5	0.03	1	1.5	1.5	2.9	0.14	2	2.3	2.8
Nov.	1.9	0.01	3	1.4	1.6	2.7	0.02	3	2.3	2.4
Dec.	3.7	0.01	4	2.2	1.3	1.9	0.02	1	1.9	1.9
Jan.	2.0	0.01	5	1.0	0.7	1.9	0.61	4	1.5	1.8
Feb.	$2.4^{\S}$	0.01	5	0.8	0.4	$2.4^{\S}$	0.06	4	1.6	1.1
			45					28		
	Tmt. 4 (low irrigation)					Tmt. 6 (low irrigation)				
Mar.	16.4	0.01	3	6.9	1.0	3.3	0.02	3	2.4	2.6
Apr.	4.9	0.02	3	3.1	2.2	1.3	0.05	3	1.2	1.0
May	1.5	0.82	1	1.5	1.5	2.4	0.02	2	2.0	1.5
June	-	-	0	-	-	-	-	0	-	-
July	10.5	0.01	3	7.0	6.1	4.9	0.01	2	4.9	4.9
Aug.	-	-	0	-	-	-	-	0	-	-
Sept.	-	-	0	-	-	-	-	0	-	-
Oct.	-	-	0	-	-	16.9	0.02	1	16.9	16.9
Nov.	10.1	0.01	1	10.1	10.1	13.6	0.01	3	7.7	7.5
Dec.	5.7	0.36	1	5.7	5.7	9.7	0.70	2	7.1	9.6
Jan.	8.3	0.01	3	6.2	3.8	7.3	0.05	3	5.0	4.5
Feb.	$2.3^{\S}$	0.16	4	1.7	1.5	$3.5^{\S}$	0.50	4	2.7	2.3
			19					23		

(continued)

TABLE D-5 (continued)

Month	Tmt. 2 (manure)					Tmt. 7 (high irrigation)				
	Highest conc. event		n	Mean concentration		Highest conc. event		n	Mean concentration	
	Conc., mg/ℓ	Volume, cm		Arith.	Vol.-wt.	Conc., mg/ℓ	Volume, cm		Arith.	Vol.-wt.
				--------mg/ℓ-------					------mg/ℓ--------	
Mar.	15.7	0.02	3	7.9	6.2	23.4	0.11	3	10.7	5.1
Apr.	5.1	3.27	3	3.6	5.0	14.5	3.27	3	8.9	14.3
May	8.9	1.29	3	4.1	8.8	10.9	0.01	4	8.9	5.2
June	1.7	0.02	1	1.7	1.7	-	-	0	-	-
July	2.4	0.02	3	1.6	1.6	8.8	0.19	1	8.8	8.8
Aug.	1.3	0.02	1	1.3	1.3	7.0	0.02	1	7.0	7.0
Sept.	2.9	0.01	2	2.3	2.2	-	-	0	-	-
Oct.	2.7	0.04	2	2.6	2.6	9.6	0.05	1	9.6	9.6
Nov.	12.3	0.26	3	5.3	10.3	32.3	0.69	2	21.9	20.0
Dec.	12.8	0.03	2	12.4	11.9	6.5	0.06	2	6.1	5.8
Jan.	11.3	0.19	3	7.1	6.6	11.4	0.01	5	7.3	4.7
Feb.	6.0§	0.62	4	4.8	4.1	2.8§	1.78	4	2.1	2.0
			30					26		

---

[*] n = number of runoff events.

[§] Snowmelt runoff.

TABLE D-6 MONTHLY MEANS AND HIGHEST CONCENTRATION FOR MARCH 1978 - FEB. 1979 FOR N

Month	Tmt. 3 (fertilizer)					Tmt. 5 (fertilizer)				
	Highest conc. event		*	Mean concentration		Highest conc. event		n	Mean concentration	
	Conc., mg/ℓ	Volume, cm	n	Arith.	Vol.-wt.	Conc., mg/ℓ	Volume, cm		Arith.	Vol.-wt.
				------mg/ℓ--------					-------mg/ℓ-------	
Mar.	4.7	0.05	4	3.5	2.8	8.7	0.05	2	5.7	2.8
Apr.	14.9	0.01	6	8.5	12.4	7.3	0.01	3	6.0	4.6
May	8.8	0.01	4	5.9	3.3	7.3	0.01	2	5.3	3.5
June	5.5	0.02	2	4.6	3.9	4.6	0.02	1	4.6	4.6
July	9.4	0.02	4	5.3	3.4	16.4	0.03	3	10.1	9.4
Aug.	4.9	0.01	5	3.4	3.0	-	-	0	-	-
Sept.	11.2	0.01	2	8.2	7.8	23.6	0.04	3	19.2	21.4
Oct.	3.3	0.03	1	3.3	3.3	8.1	0.14	2	6.0	7.9
Nov.	5.1	0.18	3	4.1	4.8	5.7	0.02	3	4.9	5.1
Dec.	13.0	0.01	4	7.2	4.0	4.5	0.02	1	4.5	4.5
Jan.	3.9	0.38	5	2.9	3.3	4.5	0.61	4	3.3	4.4
Feb.	6.3	0.01	5	3.8	3.1	6.1	0.06	4	4.7	3.8
			45					28		
	Tmt. 4 (low irrigation)					Tmt. 6 (low irrigation)				
Mar.	26.6	0.01	3	13.2	3.6	9.2	0.02	3	6.4	5.3
Apr.	10.9	0.02	3	7.9	6.6	4.2	0.07	3	4.0	3.8
May	4.8	0.82	1	4.8	4.8	5.3	0.02	2	5.1	4.9
June	-	-	0	-	-	-	-	0	-	-
July	32.5	0.01	3	18.7	16.7	17.6	0.01	2	14.0	14.3
Aug.	-	-	0	-	-	-	-	0	-	-
Sept.	-	-	0	-	-	-	-	0	-	-
Oct.	-	-	0	-	-	52.9	0.02	1	52.9	52.9
Nov.	16.4	0.01	1	16.4	16.4	19.2	0.01	3	13.2	13.0
Dec.	9.8	0.36	1	9.8	9.8	15.7	0.70	2	12.7	15.6
Jan.	17.2	0.01	3	12.5	8.5	29.2	0.05	3	18.2	9.2
Feb.	6.3	0.12	4	5.2	4.8	10.7	0.50	4	7.9	6.8
			19					23		

(continued)

TABLE D-6 (continued)

Month	Tmt. 2 (manure)					Tmt. 7 (high irrigation)				
	Highest conc. event		n	Mean concentration		Highest conc. event		n	Mean concentration	
	Conc., mg/ℓ	Volume, cm		Arith.	Vol.-wt.	Conc., mg/ℓ	Volume, cm		Arith.	Vol.-wt
				--------mg/ℓ------					-------mg/ℓ-------	
Mar.	20.2	0.02	3	11.9	9.0	37.7	0.11	3	19.2	10.4
Apr.	16.9	3.27	3	12.7	16.6	22.3	3.27	3	15.3	22.1
May	16.5	1.29	3	10.0	16.3	28.8	0.01	4	19.3	10.7
June	4.2	0.02	1	4.2	4.2	-	-	0	-	-
July	3.9	0.18	3	3.4	3.8	13.2	0.19	1	13.2	13.2
Aug.	3.0	0.02	1	3.0	3.0	10.1	0.02	1	10.1	10.1
Sept.	13.0	0.01	2	9.3	8.8	-	-	0	-	-
Oct.	5.7	0.04	2	5.3	5.6	21.0	0.05	1	21.0	21.0
Nov.	17.4	0.26	3	8.1	14.8	41.0	0.69	2	29.6	27.1
Dec.	21.8	0.03	2	19.8	17.9	16.3	0.06	2	13.8	11.4
Jan.	14.4	0.19	3	10.2	8.1	23.3	0.01	5	13.8	8.9
Feb.	31.1	0.78	4	14.4	13.2	8.6	0.77	4	7.1	6.9
			30					26		

---

* n = number of runoff events.